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Serious gaming for better cooperation in flood defence asset management

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Abstract

Flood defences are often situated in public spaces and are mostly multi-functional, multi-financed and multi-managed. Cooperation in flood defence asset management is important because roles and responsibilities are fragmented within and between organisations. This complex context calls for mutual understanding from responsible role-holders. Research has shown that serious games are instrumental to reflect situations in which technical and social complexity both play a role. Serious games motivate participants to learn and to change the way they learn. This paper presents the development, application, and results of a serious game 'Dike Dilemmas Under Pressure' that aims to create better mutual understanding between actors in flood defence asset management. The game was played with 67 professionals that fulfil a diversity of roles related to flood defence asset management in the Netherlands. The analysis of the results in this paper clearly shows different preferred cooperative attitudes between different groups of role-holders and indicates potential misperceptions. The game participants were enthusiastic about the insights gained. They indicated that it helped them to recognise the broad variety of asset management dilemmas and become aware of their own cooperative attitudes and those of their colleagues towards dealing with these dilemmas. Future application of the game is recommended to monitor the cooperative attitudes of professionals in flood defence and to support the development of teams.

KEYWORDS

asset management, education and training, flood defence measures, governance and institutions

1 | INTRODUCTION

Flood defence asset management has a long history, especially in deltaic areas such as the Netherlands, with around 60% of the area flood-prone. Cooperation in flood defence asset management becomes more and more important because roles and responsibilities are often fragmented within and between organisations (Vonk

et al., 2020). It is necessary within and between organisations (Gersonius et al., 2020) as a part of mature asset management (Volker et al., 2013).

In the Netherlands, asset management of the primary flood defences is a joint legal task of the Ministry of Infrastructure and Water Management (hereinafter the Ministry) and 21 regional Water Authorities (Ministry IWM, 2017). Their three main tasks include daily management, periodic safety assessment and reinforcements. Dutch flood defence managers have to deal with a changed standard for flood protection, an extensive reinforcement task and a new interpretation of operational flood defence asset management (Kader Zorgplicht Primaire Waterkeringen, 2015). The ambition for the accelerated realisation of dike reinforcements (Deltaprogramma, 2020) increases pressure on Water Authorities and the Ministry. This has consequences for the competence development of employees to deal adequately with complexity in reinforcement or maintenance projects (De Leeuw, 2021). Especially for reinforcements, other institutions are involved as well, such as municipalities and nature organisations. Participation and cooperation are key aspects to achieving optimal programs of managed assets (Almoradie et al., 2013). Cooperation between institutions is required as bottlenecks and dilemmas continuously arise during the process of flood defence asset management, due to differences in vision, responsibilities, financial interests, technical capabilities and organisations (Den Heijer et al., 2023). However, asset management of flood defences encounters challenges in practice, including insufficient cooperation of the stakeholders involved (Ishiwatari, 2019; Volker et al., 2013). Cooperation between professionals involved in the main flood defence tasks becomes increasingly important because choices made in one phase of the flood defence life cycle can affect another. Technical, organisational and social issues all contribute to the overall complexity of such projects. Issues include the multi-usage of public space, the cost-minimization focus, limited space for reinforcements and changes in regulations and technical insights.

De Leeuw (2021) and Den Heijer et al. (2023) show five situations in Dutch flood defence asset management in which bottlenecks and dilemmas in cooperation arose. They propose that the multi-managed practice of flood defence asset management requires 'situational cooperation', which shapes the cooperation deliberately to best enable trade-offs between interests. The situations that were studied by them express that no single 'good' shape of cooperation seems to exist; every circumstance or context may lead to a different 'best' shape. Because the situations show that Water Authorities respond ad hoc to bottlenecks, shaping cooperation should be a continuous part of flood defence asset management during the life cycle. This requires the development of a cooperative attitude of the role-holders involved. Serious games receive a lot of attention worldwide as they are enablers, motivating participants to learn and to change the way they learn (Harteveld & Bidarra, 2007). Therefore, serious gaming is proposed as one of the possibilities to support the design of cooperation in the complex field of flood defence asset management (Den Heijer et al., 2023; Khoury et al., 2018).

This prompts an urgent question: Can serious gaming create awareness about differences between one's preferred cooperative attitude and those of other responsible role-holders in flood defence management? This paper presents the development, application and results of a serious game that aims to create better mutual understanding within and between organisations involved in flood defence asset management in order to support the deliberate design of cooperation.

First, the theoretical background of social and organisational complexity in flood defence asset management and the possible role of serious gaming is described. Next, based on existing literature and objectives extracted from the professional field, we describe the development and testing of a serious game, with the intention to enable enhanced cooperation by creating awareness and enabling reflection amongst the participants. After the testing phase, the game was played with 67 participants in 14 sessions and the results of the application were analysed. Finally, a concluding discussion is given in which the main question is answered, followed by suggestions for use, limitations and suggestions for extensions of the game.

This paper contributes to enhancing cooperation in the field of flood defence asset management as the game facilitates a simple, structured analysis of cooperating organisations, teams or individuals, enabling them to discuss cooperative attitudes, effects and adaptations. Despite the educational potential of serious gaming, there is a common ground that empirical evidence is scarce and there is a shortage of fully-fledged measurements, with an emphasis on measurements with well-founded reliability and validity (Gris, 2021). This paper therefore also aims to contribute to the demand for empirical evidence of the potential of game-based learning.

2 | THEORETICAL BACKGROUND

To understand the design and testing of a tailor-made serious game for flood defence asset management, specific insight into this field is needed in the background of complexity and the different views on the same reality.

Below a short overview is given, together with an overview of the potential of serious gaming and the essential characteristics of an effective serious game.

2.1 | Complexity

Hertogh and Westerveld (2010) distinguish six types of complexities in infrastructure projects: technical, social, financial, legal, organisational and time complexity. Although all types are considered relevant, most problems are experienced in dealing with social and organisational complexity due to their intangibility and susceptibility to change (Hertogh & Westerveld, 2010). In infrastructure management, the objectives of cooperation are to increase benefits for the cooperating stakeholders. The multi-managed and multi-financed flood defences contain interaction between strategic-visionary, responsibility, organisational, financial, spatial, and technical aspects (De Leeuw, 2021). Asset management for flood defences is organisationally complex due to the fragmentation of roles and responsibilities within and between organisations (Deltares, 2020; Den Heijer et al., 2021; Dieperink et al., 2014). This complexity is increased by competing for functional demands in the public space and financing issues (Vonk et al., 2020). Den Heijer et al. (2021) state that one of the actual trends to deal with flood defence management complexity is to decrease interactive complexity.

2.2 | Different views on reality

Social and organisational complexity is characterised by differences in the interpretation of objects, roles and responsibilities. The more individuals and thus perspectives, the higher the complexity would be (Bergman & Beehner, 2015). In flood defence asset management, several roles are included in the three main tasks, often being distributed amongst different organisations (Den Heijer et al., 2023; Dieperink et al., 2014). Any mismatch in interpretation can undermine the successful or timely execution of tasks crucial to flood defence management. Adding to the complexity is that different perspectives of these roles are heavily guided by self-interest (Hertogh & Westerveld, 2010).

Following Hertogh and Westerveld (2010), social complexity can be viewed from the outside as well as experienced from within. In this paper, the social complexity from the outside is relevant, as it manifests in the interaction between different individuals or organisations. For example, a project manager of a dike-strengthening project wants to apply an innovative reinforcement technique that fits the sustainability vision of their Water Authority. Innovation can lead to improvement, and moreover, the Water Authority would gain a progressive reputation. However, the operation and maintenance manager responsible for the flood defence condition considers the application of innovative reinforcement techniques a risk. Due to unfamiliarity with monitoring such techniques, he is unable to properly assess the flood defence conditions and thus cannot guarantee its safety conditions. The project manager considers the operation and maintenance manager to be too conservative, while the operation and maintenance manager considers the program manager to be unrealistic.

It is not surprising that issues within a certain phase of the flood defence life cycle are not experienced as complex by practitioners who are responsible for other phases of the flood defence life cycle. Building upon Aureli and Schino (2019), a refined view of relationships within and between asset management levels is needed to embrace the complexities faced by individual practitioners in the flood defence life cycle. The starting point for this study is that serious gaming can be instrumental.

2.3 | The potential of serious gaming

Serious games combine a serious purpose with elements of gaming (Abt, 1970; Djaouti et al., 2011; Sawyer, 2007) so that they are educational, realistic and playable (Harteveld, 2011). Several types of games exist, such as video games, simulations, card and board games. Serious gaming provides participants with a safe environment to experiment in, take on a different role and defend positions that they may not occupy in reality. Duke and Geurts (2004) mention 'understanding complexity' as one of the goals of serious games, in addition to stimulating creativity, improving communication and reaching a consensus. In recent years, serious games have been designed and applied to deal with complexity (Bekebrede, 2010; Bellotti et al., 2010; den Haan et al., 2016; Harteveld, 2011; Meijer, 2012). The results of playing these serious games are amongst others increased awareness, training and a shared understanding. This makes serious games a good means to increase capacity to deal with the complex socio-technical context of water management in the Netherlands (Den Heijer et al., 2021; Den Heijer et al., 2023).

To design a serious game that creates mutual understanding between role-holders in the complex environment of flood defence asset management, it is essential to understand serious gaming and its design elements from a theoretical point of view. Generally, serious games can be divided into process-oriented games and outcome-focused games (Designing Digitally, 2019). Process-

TABLE 1 Overview of essential characteristics for effective serious game design, based on existing serious gaming literature.

Composed serious game taxonomy in order of most mentions	Characteristics of gaming methods and approaches Zhou et al. (2013)	Serious gaming 'flow' (Diepersloot, 2019; Pavlas et al., 2010)	The elements of participant experience (Ferrara, 2011)
	To achieve the characteristic in the 1st column the serious game should		
1. Valuable: the game is valuable when the process and outcomes provide guidance for the participant's daily practice, making personal development a motivation to play.	...convey meaning and insight about the problem (communicative)	...ensure deep involvement in the activity (involvement)	...be short-term interesting and long-term rewarding (motivation)
	...react to the decisions of participants (dynamic)	...give a sense of control over participant's actions (control)	...attribute game effects to an understandable cause (usability)
2. Simulative: the game is simulative if game events are selective representations, but accurately resemble reality.	...incorporate analytical and political standards for useable outcomes (authoritative)	...remove concern for oneself during immersion (no self-awareness)	
	...provide clear and understandable results for all participants (transparent)	...alter the participant's sense of time (time awareness)	
3. Interactive: the game gives interactive feedback when the decisions of participants are directly responded to either by fellow participants or via a reward system so that participants can adjust their tactics/strategy.	...support negotiation between participants (interactive)	...give immediate feedback on the decisions of participants (immediate feedback)	...stimulate the development of tactics and strategies to influence the outcome (meaningful choices)
	...react to the decisions of participants (dynamic)		
4. Increasable: the game increases in difficulty when the participant's ability to play grows.	...consider different levels of design and decision making in a holistic and systematic way (integrative)	...be successfully completed (completion)	...be equitably balanced to satisfy, not frustrate (balance)
5. Unambiguous: the game is unambiguous when minimal sensory distraction causes full immersion.		...stimulate concentration so that the participant can immerse in the activity (concentration)	...set a tone through aesthetic choices (aesthetics)
6. Scalable: the game is scalable when it is widely accessible, implementable, and easy to moderate.	...be quickly applicable and usable for non-experts (fast and easy to use)		

Note: To shorten the texts in the second, third and fourth columns, read them as 'The serious game should'. These descriptions are based on literature mentioned in the column header (between brackets the terminology used in that very literature).

oriented games are simulations that uncover the strengths and weaknesses of a team and offer room for improvisation which allows participants to safely improve their skills or awareness. Outcome-focused games train participants in essential skills and can be used to change the perception and attitudes of stakeholders. In the case of the absence of mutual understanding, as seen in flood defence asset management, process-oriented games prevail. Hence, this was incorporated into the game design.

In literature about gamification and serious game design, characteristics of game design are often listed (Diepersloot, 2019; Ferrara, 2011; Pavlas et al., 2010; Zhou et al., 2013). Based on this literature, we composed a theoretically substantiated checklist, presented in Table 1. The second, third and fourth columns provide characteristics mentioned in the corresponding papers as mentioned in the column header. Since the papers use different naming of the characteristics, we composed a taxonomy in six main categories of characteristics, provided in the first column, ordered by the most mentioned characteristics. The categorisation and names of all characteristics are based on the extended descriptions in the original papers.

3 | METHODOLOGY

We aim to support the deliberate design of cooperation in flood defence asset management. In this paper, the results of playing a serious game with multiple role-holders in flood defence asset management are analysed in terms of the game's capacity to enable better mutual understanding between the different roles and responsibilities within and between organisations involved in flood defence management.

To thoughtfully develop a meaningful and effective game, we distinguished four stages, containing the starting points and design of the serious game, and the application and analyses, respectively. We introduce them in this section briefly with a flow chart of the stages and the important steps (see Figure 1) to provide an overview of the methodology and refer to the sections for the detailed elaboration.

4 | STAGE 1: GENERAL DESIGN OF THE SERIOUS GAME

Developing a serious game is, just like playing a game (Corti, 2006; Hummel et al., 2011), a 'learning-by-doing' process with an important 'trial-and-error' component. Existing literature on serious gaming offers starting points for game design, which are added with requirements from the professional field. The game has been developed through an interactive process within the development team, consisting of professionals in flood defence asset management from Water Authorities, the Ministry, the Foundation for Applied Water Research (whose Dutch acronym is STOWA), universities, research institutes, and private companies.

The starting point was to build a process-oriented game with a strong focus on relational learning, as the

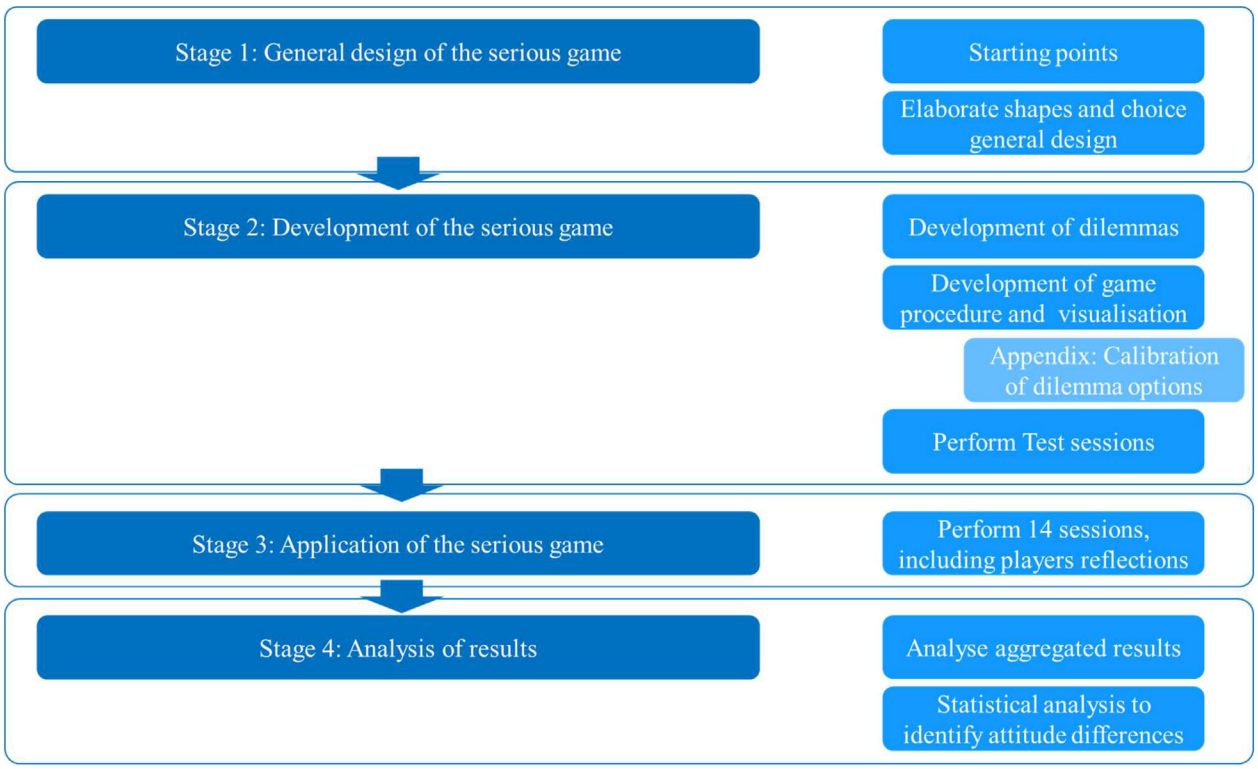

FIGURE 1 Overview of the methodology.

main purpose of the game was to develop awareness (Baird et al., 2014; Designing Digitally, 2019).

With the theoretical background as the basis, the following requirements were taken into account during the game design (between brackets the reference to the taxonomy in Table 1):

- The game should be able to simulate social complexity emerging from interactions between practitioners as well as complexity experienced by the interacting individual (Simulation).
- The game should contribute to participants' insight into different roles, gained through the simulation process and outcome reflection. It should approach real practice (Valuable).
- The game should be a selective representation of reality to keep it playable. However, playing the game should offer a clear resemblance to real-world situations (Den Heijer et al., 2021). It should provide participants a safe space to experiment in, for example, to take a position that they would not occupy in practice. Nevertheless, the simulation should contain as many factors that characterise the situation of real position holders, such as time pressure and available resources (Simulation).
- The game should respond to the participant's actions through in-game feedback or discussion between participants (Interactive).
- The game should become more complex and challenging as the participant's ability grows in playing the serious game (Annetta, 2010; Diepersloot, 2019) (Increasing difficulty).
- The game should offer participants an immersive environment to role-play. Sensory distractions (e.g., different font sizes, hard colours, jargon) should be minimalized through stylistic (writing) choices (Unambiguous).
- The game should be playable by (large) project teams and able to reach a relatively large target audience (Scalable).

Adding to the theoretical input for game design, the following practical starting points and boundary conditions were defined with the development team:

- The game must be playable within the context of a single organisation (e.g., Water Authority) and with different hierarchical levels (Valuable).
- The maximum duration of the game is 1 h (Scalable).
- The game must be playable both virtually and physically (Scalable).

To address these requirements, three games were set up to stimulate the 'learning by doing' process:

- *Diggers in dikes*: An interactive and linear board game in which a team of participants propagates on the board by throwing dice and giving correct answers to questions about beaver management. The team's opponent is the beaver who propagates autonomously through a series of fixed events. Participants win when they reach the finish line before the beaver does. The game allowed players to share perspectives on beaver management decisions, and can therefore enable the exchange of knowledge, increase awareness, and improve collaboration. The game is focused on the operational flood defence asset management level. It is recommended to incorporate strategic and tactical levels, which contribute to enhancing multi-level collaboration. This allows professionals of the strategic and tactical levels to actively engage in the serious game.
- *Scenario memory game*: A structured-discussion game that supports the development of an approach for reinforcement of a certain dike trajectory through scenario development. Spread out over multiple weeks, participants progress through four game phases: stakeholder inventory; inventory of influences, interests, linkage opportunities, and risks; scenario development; and scenario choice. The scenarios are situations devised by participants to link interests with each other. The game aims to reduce the complexity of the trajectory approach and improve cooperation within the departments of a Water Authority. For every phase, participants come and go. For example, in the decision-making phase, department heads and budget holders join. Every phase, therefore, has to start with an introduction, an explanation of the current phase and a summary of the previous phases.
- *Successful innovation*: A point-based roleplaying game in which participants mimic the design, management, and assessment phases of an innovative dike improvement. A team chooses two random cards: a case of an insufficient safe dike section, and a description of the soil structure underneath the dike. With this combination, participants in turn have to propose innovative solutions based on their roles. Roles have unique assignments that lead to a shared goal. Completing assignments, either individually or as a group, results in points. Participants win when they receive enough points to reach the level 'Expert'. The starting point is that participants put themselves in the position of (other) flood defence managers to create a problem-solving ability based on the interests of their role.

TABLE 2 Overview of the different games related to the extent they meet the essential characteristics for effective serious game design.

Serious game taxonomy	Diggers in dikes	Scenario memory game	Successful innovation
1. Valuable	−	+	+
2. Simulative	−	+	+
3. Interactive	+	0	+
4. Increasable	−	−	−
5. Unambiguous	0	0	−
6. Scalable	−	−	−

Note: In the rows, the serious game taxonomy is provided in Table 1.

In Table 2, an overview is given of the extent to which these three games meet the requirements as evaluated by the development team aggregated on the serious game taxonomy in Table 1. Following this elaboration, these games do not sufficiently meet the essential characteristics for effective serious game design.

Based on these experiences, the development team designed 'learning by doing' a game that sufficiently meets the requirements and essential characteristics: an immersive roleplaying game in which participants are challenged, under time pressure, to decide between two choices in complex flood defence asset management dilemmas. With themes such as daily operation, organisation management and project management, the game encourages participants to think 'what would my role do in this situation'. The starting point is that participants put themselves in the position of (other) flood defence managers and gain a greater understanding of the complexity of their roles and responsibilities. A layer of argumentation of the choice is added to share individual opinions and beliefs within participating teams. This *Dike Dilemmas Under Pressure Game* is chosen for further development, application and analysis to meet the objective of this paper.

5 | STAGE 2: DEVELOPMENT OF THE SERIOUS GAME

5.1 | Game content: Development of dilemmas

A subset of the development team described the context of a few dilemmas to serve as examples for an inventory with practitioners. They are described in the Dutch language as preferred by the Water Authorities, taking a maximum of 100 words in mind. Dilemmas usually indicate choices of two or more alternatives that are equally (un)desirable. Therefore, the dilemmas were completed with two choices on how to approach them. Both may be right, so there is no best answer.

About 40% of all Water Authorities in the Netherlands were asked to deliver such dilemmas. In total, 25 responses were received, which we developed into 100 word-dilemmas. We structured the dilemmas in three themes corresponding to the roles of operation and maintenance manager, organisational manager (e.g., department head or director), and project manager of a dike reinforcement. An example of a used dilemma is shown in Figure 2.

5.2 | Game procedure: Read, choose, motivate!

The core of the game is to run through 18 or 20 rounds of dilemmas and to decide between two choices on what a professional in a designated role would do in such a situation, representing their behaviour under time pressure. Sessions contained 18 dilemmas in the case of three, six or nine participants. With group sizes of four, five, or ten participants, the game contained 20 dilemmas. For different-sized groups, a tailor-made version can be made.

The structure of each round is always the same: *read* the dilemma, *choose* between option A or B, and *motivate* your choice to the other participants. It is alternately up to one participant to present their motivation to the other participants. The other participants form a 'panel' who rate the participants' argumentation (0 for no argumentation, 1 for a bad, 2 for moderate, 3 for a good argumentation). An important aspect of the game is that there is no right answer to a dilemma. The 'panel'-participants are not allowed to change their own choice based on the presented argumentation.

If the players earn together more than 60% of all possible points, they jointly win the game. But only one participant can win the title 'Master of Dilemmas'. This title is awarded based on what players consider most important: the player who gave the highest rates to others (most receptive player), the player who received the highest rates (most convincing player), or the aggregate of the

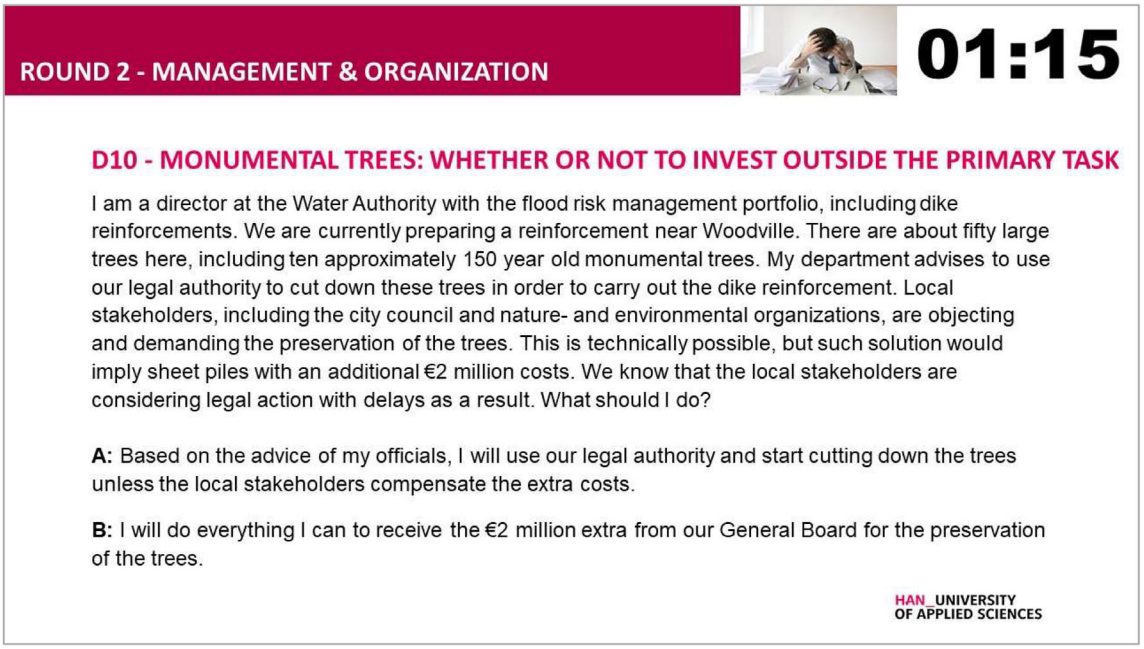

FIGURE 2 An example of one of the 20 dilemmas from the game, in this case, dilemma D10 from round 2-organisation & management (translated from Dutch).

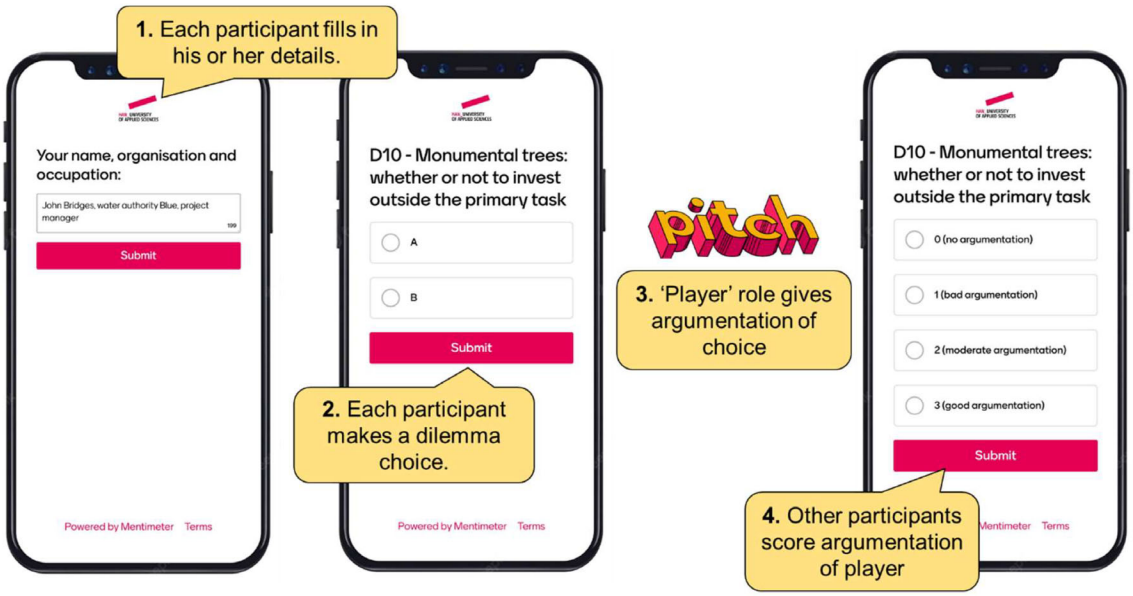

FIGURE 3 An example of the Mentimeter app together with the participant's required actions during the game (translated from Dutch).

two. After the group decides on the winning criterium, the Master of Dilemmas is announced.

A game leader and a facilitator support the process. The game leader announces the dilemmas and asks the participants to motivate. The facilitator collects the choices of the participants. Every participant joins a Mentimeter session where they can enter their own choice (A or B) together with the scores (0–3) of the given explanation by one of the participants (see Figure 3). These choices are directly transferred to an overview spreadsheet managed by the facilitator. This allows the facilitator to announce when a participant forgets to enter a choice.

5.3 | Game output and visualisation

The results are threefold: a group-score which expresses the degree of valuation of the participants'

argumentations, an individual score for most points received from and given to others, and the results of participants' dilemma choices reflecting or 'mirroring' the behaviour of the individual participants. After the last dilemma round, the game leader presents the results of the scores and discusses them with the participants in a structured way.

The group score is the relative sum of all given scores of the participants and reflects the ability of the group to listen and value others' argumentations. The individual scores are simply the sum of all received scores and the sum of the given scores. Received points reflect the quality of individual argumentations, and the given points reflect each participant's ability to listen and value members' argumentations. The results in the third part are mirror-like figures. A real mirror shows what you look like, and the 'mirror plot' shows participants' preferred behaviour with respect to cooperation.

The mirror with the relative behaviour of the individual participants is presented on the axes as used in Den Heijer et al. (2023), see Figure 4. For the horizontal axis, the intensity levels of cooperation defined by Sadoff and Grey (2005) have been used, clustered in Task-oriented (unilateral, coordination) and result or Goal-oriented shapes of cooperation (collaboration, joint action), respectively denoted by T and G. For the vertical axis, a distinction has been made between Internal (within the participants' institution) and External (outside the participants' institution) cooperation, corresponding with the Infrastructure Asset Management Maturity Model (Volker et al., 2013), respectively denoted by I and E. Thus, there are four quadrants in these plots (ET, EG, IT, IG). A dilemma contains two options. Each option reflects a score in one of the four quadrants. In the example of Figure 2, option A reflects Internal and Task-oriented behaviour. It reflects participants' preference for quadrant IT. Option B is Goal oriented, trying to comply with stakeholders' demands. It reflects participants' preference for quadrant EG. In the same way, quadrant IG suggests an attitude to obtain goals, however, using only the own institution. The quadrant ET suggests an External attitude, however, performing only the own task.

To reliably represent the results, special attention is given to the position of each dilemma choice, as it should reflect the participants' perception of the best attitude for this dilemma. Participants start at the centre of the plot: $x = 0; y = 0$. Each dilemma choice should move a participant towards one of four quadrants. All dilemmas are considered equally important. Because there are two axes to move on, this would imply that a dilemma choice with the position ET moves the participant $x - 1; y + 1$, and IG moves the participant $x + 1; y - 1$. The plotted position of a participant is the sum of displacement divided by the number of dilemmas. The Centre point reflects the average position of all dilemma options in the Figure. The contour of possible outcomes reflects the surface of possible scores. In the Appendix, the calibration of the dilemma choices on quadrant positions is given. In this way, the plotted position could be interpreted as the mirror of the participants preferred attitude.

The results 'mirroring' the behaviour consists of four figures reflecting the relative cooperation behaviour per participant: one for all dilemmas and three for the roles of operation and maintenance manager, organisational manager, and project manager of a dike reinforcement. A fifth figure reflects the relative cooperation behaviour per role. All figures do have the same axes and layout as Figure 4. Because the participants are asked to empathise with those roles, these 'mirror plots' offer insight into how participants interpret the behaviour of the role-holders. These figures are used as a tool for reflection of preferred attitudes.

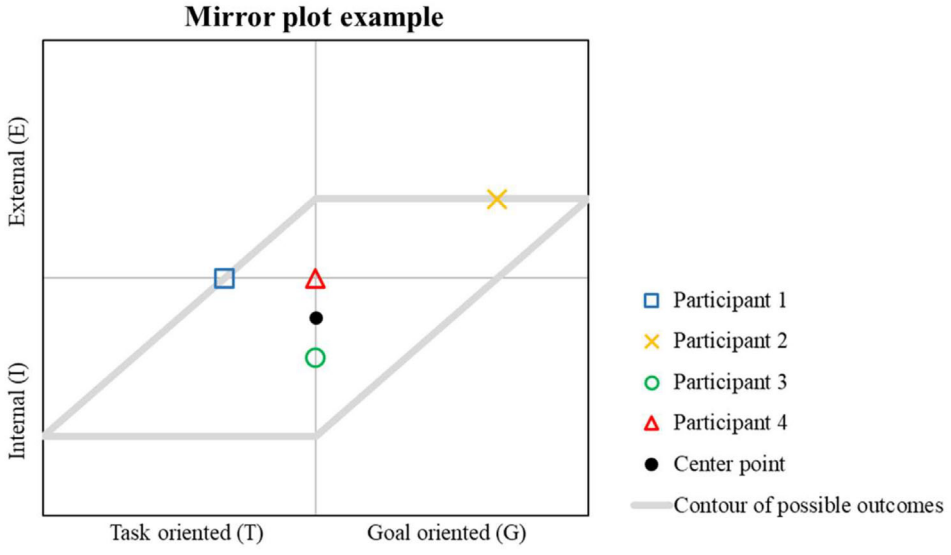

FIGURE 4 An example of a 'mirror plot' in which the dilemma choices are shown. The horizontal axis reflects the intensity levels of cooperation, clustered in Task-oriented (T) and result or Goal-oriented (G) shapes of cooperation. The vertical axis distinguishes Internal (I) and External (E) cooperation.

5.4 | Reflection phase

In the reflection phase of the game, participants are confronted with the effects of their choices by walking through the mirror plots, as seen in Figure 4. The game leader asks the participants whether the dilemmas were recognisable, whether they recognise their plotted attitude, whether the time pressure could have affected their answers, whether they appreciate other participants' explanations, whether they observe their attitudes in practice and what the results mean for cooperation regarding flood defence asset management.

5.5 | Test sessions

During development, the game was pilot tested with 4 researchers and 14 professionals employed at organisations participating in the project, who were not members of the development team. Feedback is collected by their intuitive feedback during the game and reflection afterwards. The serious game was adjusted based on their feedback.

After completion pilot-test sessions were conducted with two Water Authorities, STOWA, a group of hands-on serious game developers, and the Advisory Committee of the project. Given the cumulative work experience of those involved as well as their different backgrounds, a broad view of the current game was obtained. The main findings from these sessions were some practical issues, such as precise formulations of the dilemmas and the lead-time per dilemma to exert enough pressure on the participants. A positive comment resulting from all test sessions with professionals was the authenticity of the dilemmas. During the test sessions, the game design improved through an iterative, empirical process.

6 | STAGE 3: APPLICATION OF THE SERIOUS GAME

The serious game was applied in 14 sessions with 12 different organisations: Water Authorities with a formal responsibility related to Flood defence asset management ($n = 9$), Engineering/Management Consultancies who assist flood defence managers ($n = 3$), an Applied Knowledge Institute that exclusively works for Water Authorities ($n = 1$). In accordance with the given project starting points, the participants of each session are from the same organisation.

The Water Authorities managing primary flood defences were approached to participate. This resulted in the participation of 67 professionals, with the professions of design, assessment and consultancy being most present. Two professionals did not give a choice for all dilemma rounds. They are excluded because their scores are not comparable with the others. An overview of all sessions is shown in Table 3. The group 'Other involved staff personnel' is larger than the other groups because it consists of consultants, covering a variety of disciplines.

To minimise misinterpretation by participants during the game, an explanation of the serious game was prerecorded and presented at the start of each session (about 5 min). The game leader guides the participants through the dilemmas and safeguards the given reading-, pitching- and scoring time. The facilitator monitors the input of participants and intervenes in case of deviation.

Most sessions were facilitated by the Sustainable River Management research group. Occasionally, external partners and involved students were invited to take on a moderating role. All facilitators have been trained on how to conduct the game. Thirteen sessions were conducted digitally, one physically.

Together, the participating organisations covered a variety of different management areas, as seen in Figure 5. We assume participants of all organisations as a sample from a homogeneous population.

The last agenda point of each game session was to reflect on the game and the results. The game leader asks the participants whether the dilemmas were recognisable, whether the time pressure could have affected their answers, and invites the participants to reflect on their scores, and whether they recognise them in their own behaviour. Recurrent remarks and observations were:

- Participants enjoyed the game. It is fast, within an hour you get the results. It is exciting because of the motivation participants have to give when it is their turn.
- Participants experienced it as very interesting because the dilemmas came from the professional community of the participants, thus they address their daily practice: 'The dilemmas are very recognizable', and 'This dilemma is very similar to one in our Water Authority'.
- In most cases, the participants recognise their attitude given by the results.
- Participants tried to interpret the group results: 'Directors inspire their employees to behave Goal- and Externally oriented, but these game results show others observe that they do not practice this attitude themselves'.
- Participants experienced the game as an exercise to listen with an open mind:'Although I did not agree with the choice of another participant, I could understand and appreciate their explanation', 'After hearing an explanation, I regret being not allowed to change my choice', 'It was a challenge to not discuss after hearing other's explanations', 'It was difficult to value the explanation of the pitchers when they choose not the same option as I did'.

TABLE 3 Overview of participating organisations and professions.

Organisation	Number of participants	Area of profession of participants			
		Operation & maintenance management	Organisation management	Project management	Other involved staff personnel
Scheldestromen (WA)	5	1	-	-	4
STOWA (AKI)	4	-	3	-	1
Rivierenland (WA)	3	-	-	3	-
BZIM (C)	3	-	-	1	2
APPM (C)	4	-	-	3	1
Rijkswaterstaat (WA)	3	1	-	-	2
Provincie Noord-Holland (WA)	4	-	-	-	4
Witteveen + Bos (C)	5	-	-	-	5
Hollands Noorderkwartier I (WA)	4	2	-	-	2
Hollands Noorderkwartier II (WA)	6	3	1	-	2
Hollands Noorderkwartier III (WA)	4	-	-	1	3
Rijn en IJssel (WA)	6	2	-	3	1
Hollandse Delta (WA)	9	2	3	3	1
Schieland en de Krimpenerwaard (WA)	5	2	1	-	2
Total: 14	**65**	**13**	**8**	**14**	**30**

Abbreviations: AKI, applied knowledge institute; C, consultancy; WA, water authority.

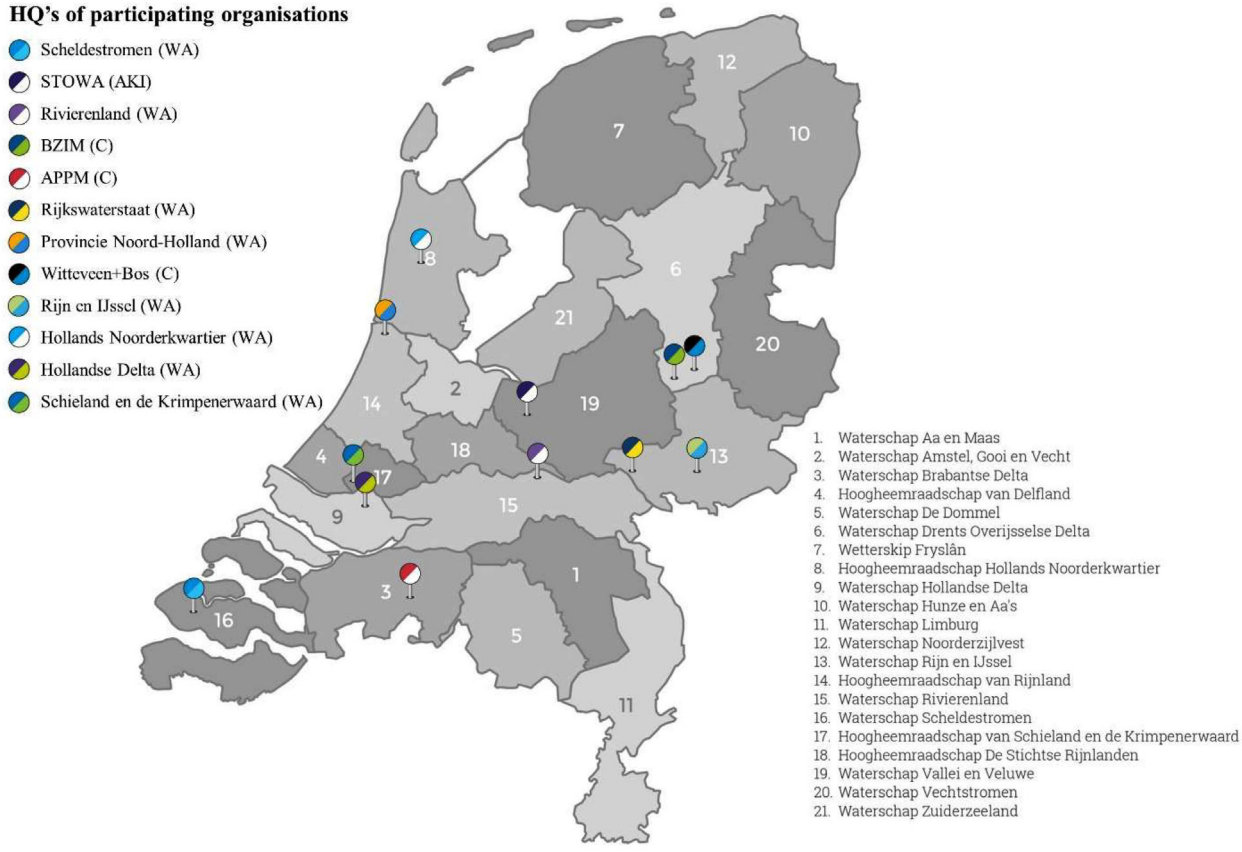

FIGURE 5 Headquarters of participating organisations, showing that a variety of different management areas are covered (adjusted from Unie van Waterschappen, 2018). AKI, applied knowledge institute; C, consultancy; WA, water authority.

- Participants and others who attended the game sessions suggested using this game approach for team building and for monitoring professional attitudes.

In the sessions, the participants were very unanimous to choose the 'Master of Dilemmas' (appointed winner) as the person with the highest sum of the got scores for explanation and the given scores. This person was interpreted as giving the best argumentations and being the most open-minded listener.

7 | STAGE 4: ANALYSIS OF RESULTS

7.1 | Mirror plots

The analysis provides insight into the cooperation attitudes and (mis)perceptions of all participants in all sessions together. The participants are divided into four groups based on their roles in daily practice. Three of them correspond with the three themes. The fourth group of participants contained other involved staff personnel such as consultants, designers, and specialists. The game results are presented on mirror plots in Figures 6, 7 and 8.

Figure 6 shows the individual scores of the participants. Figure 6a presents the results for all dilemmas together. Each marker represents a participant's position following their choices per dilemma in one of the sessions. The results are presented with different markers for each group of participants.

To examine whether the participants score differently for different themes, Figure 6b,c,d show the individual scores for respectively the themes Operation and maintenance management, Organisation management, and Project management. This mirror plot displays average scores over the number of rounds of dilemmas that relate to a particular theme. The regular patterns and overlain symbols in Figure 6b Operation and maintenance management, and Figure 6d Project management origin from the standard number of six dilemmas used for these themes in all sessions, leading to a step size of 1/3 quadrant. The contour of possible scores is derived by a Monte Carlo simulation with one million draws, being virtual participants. Each random draw of a set of options for each of the dilemmas leads

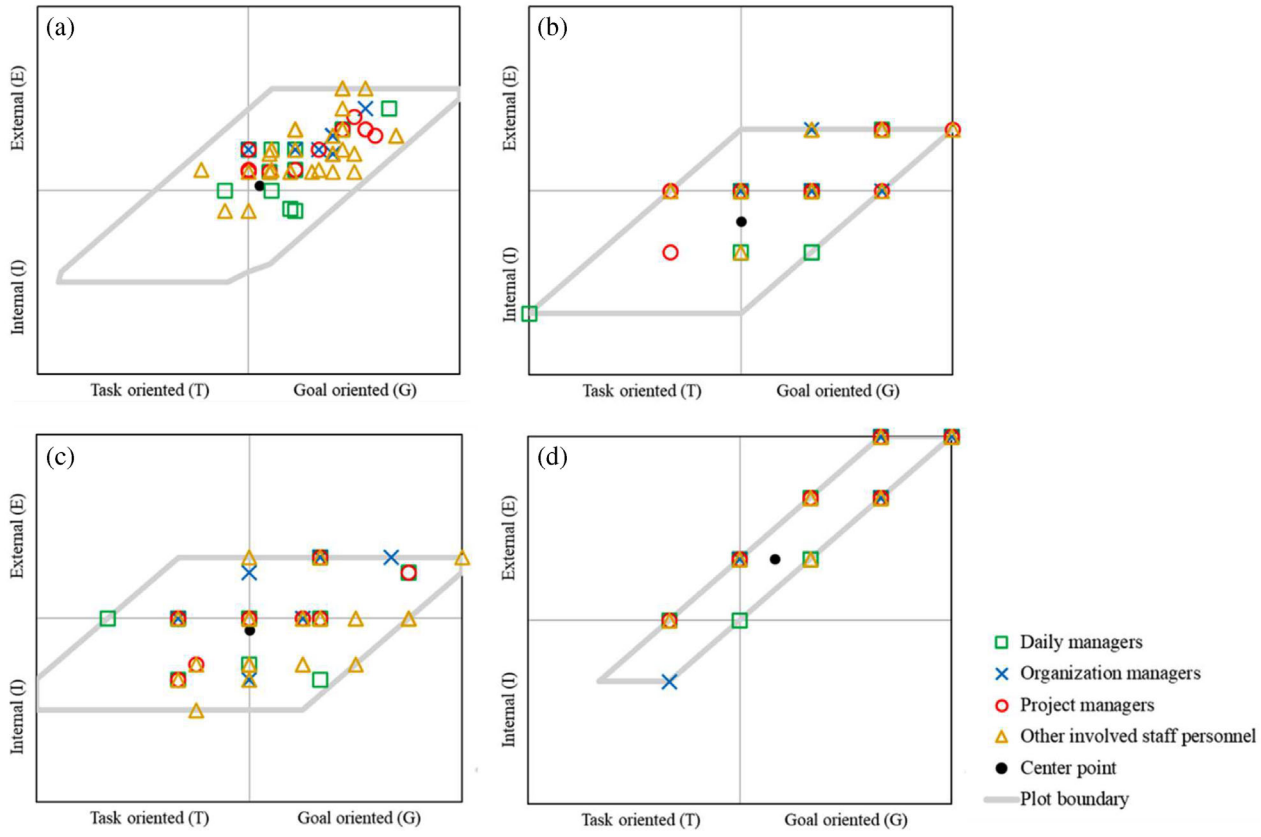

FIGURE 6 All participant scores in (a) all themes, (b) theme operation and maintenance management, (c) theme organisation & management, and (d) theme project management.

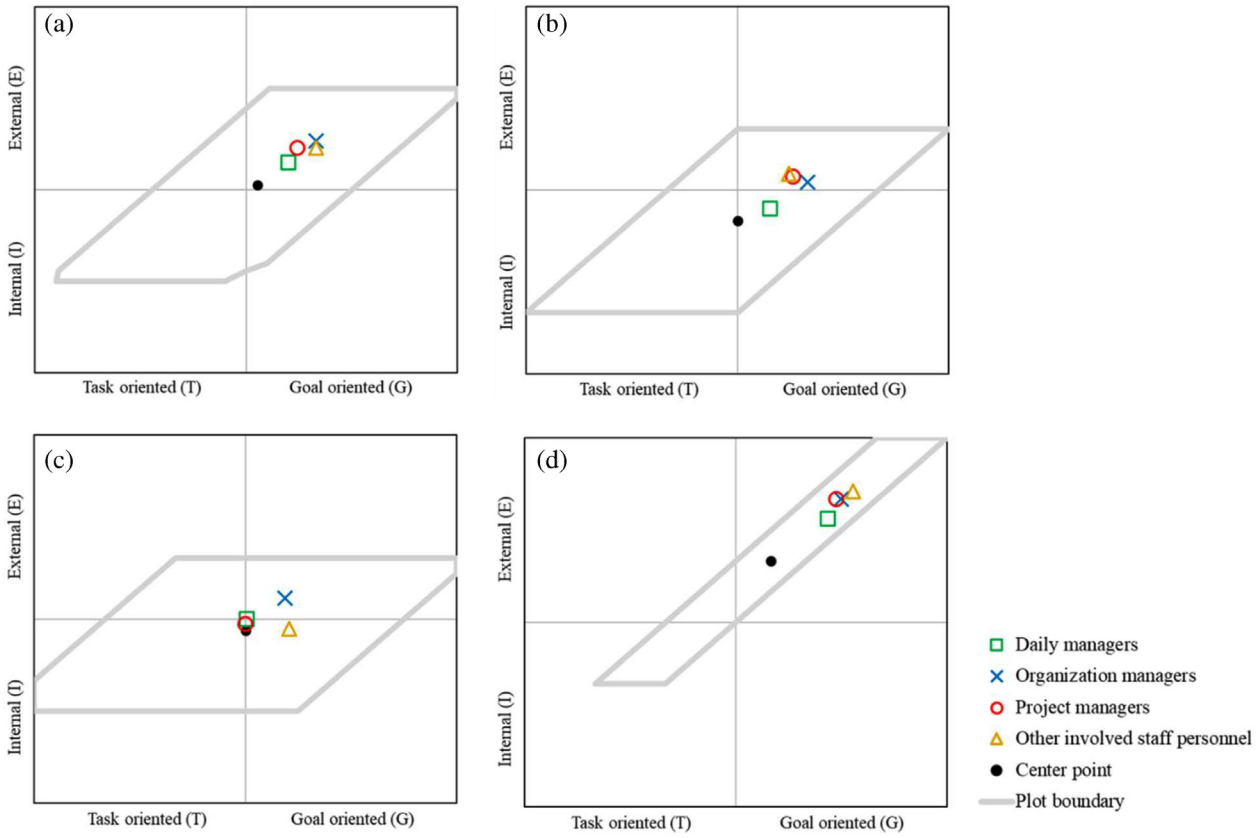

FIGURE 7 Average participant scores of (a) all themes, (b) theme operation and maintenance management, (c) theme organisation & management, and (d) theme project management.

to a dot in the mirror. The contour is the envelope of all million dots. The insights based on Figure 6 are mainly factual:

- The scores are mostly in the External and Goal-oriented quadrant (EG), indicating the preferred attitude within the sample of the professional community included in this study.
- Apparently, the used set of dilemma options, derived from dilemmas experienced in practice provided by Water Authorities, covers only a part of the whole space in the quadrants.
- The surfaces within the contours are well covered in the results per theme, reflecting the diversity of the answers by the participants.
- Figure 6a shows less spread in the plot for all themes relative to the spread in the plots per theme. When participants would have chosen the same attitude in all three dilemma rounds, the spreading would have been similar in all plots. Apparently, the participants did not score according to the same attitude in the different themes.

To further examine the scores, Figure 7 shows the average positions for each group of participants with the same role in daily practice. The contours are the same as in Figure 6. Figure 7a shows the average for all themes. Figure 7b,c,d show the average scores for the subset of dilemmas corresponding with the theme. The insights based on Figure 7 provide a qualitative interpretation of the attitude of the different groups:

- The average scores in all plots are equal or more Goal-oriented with respect to the Centre point of all options. This reflects the main attitude within the sample of the professional community included in this study.
- In the averages, the subsets differences especially between the operation and maintenance managers and the other roles are observed. In no theme, they score more Goal-oriented than all others, and except for the theme organisation & management, they score more Internally oriented.
- The relatively large deviation from the Centre point for the theme of Project Management is also remarkable. Apparently, although project managers have a clear task, participants were relatively more Goal oriented and Externally focused when simulating this role.

Figure 8 shows an overview of the average scores per theme. In fact, this Figure shows average group attitudes.

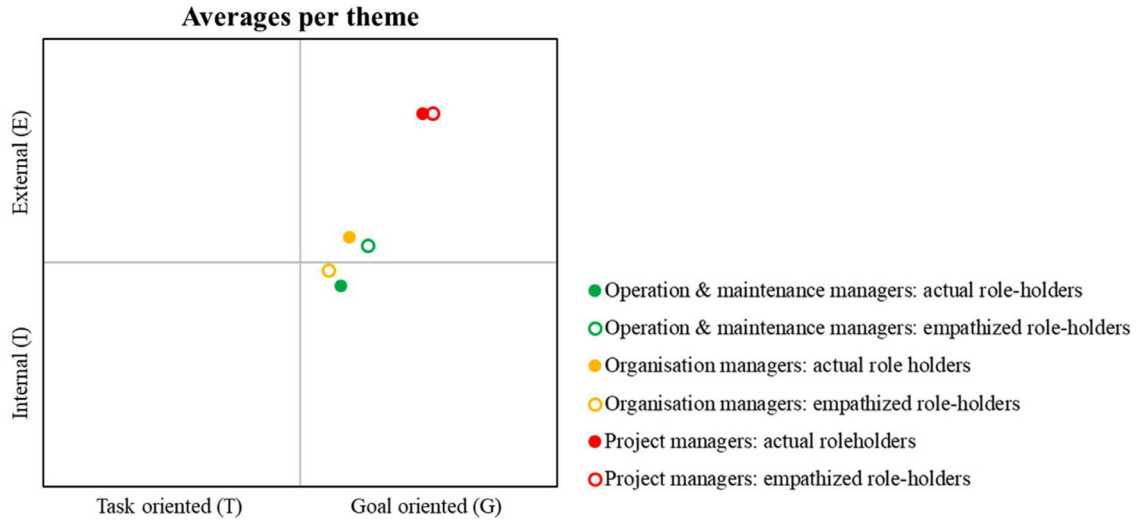

FIGURE 8 An overview of averages per theme with a distinction between actual role-holders and professional colleagues who empathised themselves with the theme's role.

The full dots are the average scores of the participants in their 'own' theme (e.g., project managers in the theme of Project Management), the open dots the average scores of all other participants for that same theme, hereafter called empathised role-holders, reflecting their thoughts about the attitude of the actual role-holder in the theme. The insights based on Figure 8 provide a qualitative interpretation of the attitude of the different roles in Flood defence asset management, and the difference between the attitudes of actual role-holders and empathised role-holders:

- Especially the scores in the theme project management are Goal- and External-oriented. Both the actual role-holders and others think more or less the same about their attitude with respect to the dilemmas in this theme.
- Interesting are the other themes. The organisational managers express more External orientation in their scores than others do when being asked to step in their shoes.
- The opposite applied to operation and maintenance managers and the theme of Operation and maintenance management. The actual role-holders see themselves as more Internal oriented than others do.

7.2 | Statistical analysis of results

In order to verify whether the differences between the visualised group attitudes in Figures 7 and 8 are quantitively relevant as well, it is necessary to assess their statistical significance. An Independent Samples *t*-test is conducted to investigate whether the associated population subset-averages are significantly different (Gosset, 1908). This method compares the means of two independent groups, with the independence in this study being ensured by disallowing communication between participants during the game.

To obtain reliable results, the sample size has to be sufficient, which we evaluate with standard techniques (Cochran, 1963). The estimated total population is about 2.500 people employed by Water Authorities in flood defence asset management [ca. 25% of 9.753 (H2O, 2020)]. Though in social sciences a 95% confidence interval (CI) is typical, a 90% CI is acceptable due to our relatively small population size and the qualitative, nominal nature of the data that consists of opinions and beliefs that are collected under time pressure (Hair et al., 2009; Hazelrigg, 2009). With a confidence interval (CI) of 90% and a margin of error of 10%, a sample size of 67 is theoretically adequate to draw conclusions for the population. The sample size in this study is 65, which is considered to be sufficient.

To execute the *t*-test, the mean, sample variance and standard deviation are calculated for each role. Because the concept of a single standard deviation does not generalise well for two dimensions (latitude and longitude), the *t*-test can only be performed for each axis separately. In other words, for any comparison of roles, two *t*-test calculations are performed: one for Task- or Goal-oriented behaviour and one for Internal or External focus. Therefore, it is possible that there is a significant difference between the two positions on the y-axis (Internal or External focus), but this significance may not be present on the x-axis (Task- or Goal-orientation).

The *t*-test is executed for the six possible combinations of the four different roles. Each role-combination is tested

for four different subsets of dilemmas (all, and the three themes) and two axes. Furthermore, for each theme, the differences between the actual role-holders and the empathised role-holders are tested. This brings a total of 54 *t*-test calculations. The significance of this study is defined at the 0.1 level, reflecting an error margin of 10%. Table 4 shows the eight combinations which turned out to be significantly different. All other combinations do not show a significant difference, implicating the roles' attitudes do not deviate that much. In the last column of Table 4, a possible explanation is given. The table contains the subgroups when the *t*-test point out a difference in one or both axes. The insights based on Table 4 provide a quantitative statistical basis for the differences in attitudes between role-holders in flood defence asset management, and between actual role-holders and empathised role-holders. The most significant differences are found for operation and maintenance managers and for other involved staff personnel. This may imply that:

- the operation and maintenance managers' attitude is deviant from other's impressions
- the staff personnel who do not take on a responsible role in one of the three themes at all show a different attitude than the actual role-holders, in particular for the theme organisation and management.
- When participants empathise with the attitude of a role-holder they show a different attitude than the actual role-holders, in particular for operation and maintenance managers and organisation managers.

TABLE 4 Overview of combinations with error-values lower than 0.10, indicating significant differences between populations are very likely.

Theme	Axis	Role-group I	Role-group II	Explanation
Total	Task- or goal-oriented (x)	Operation and maintenance managers	Other involved staff personnel	Operation and maintenance managers are more task-oriented than others think or wish they are.
Operation and maintenance management	Internal-external (y)	Operation and maintenance managers	Project managers	Operation and maintenance managers are more Intern-oriented than project managers think or wish they are.
Operation and maintenance management	Internal-external (y)	Operation and maintenance managers	Other involved staff personnel	Operation and maintenance managers are more intern-oriented than others think or wish they are.
Organisation & management	Task- or goal-oriented (x)	Operation and maintenance managers	Other involved staff personnel	Operation and maintenance managers are more task-oriented than others think or wish they are.
Organisation & management	Task- or goal-oriented (x)	Project managers	Other involved staff personnel	Project managers are more task-oriented than others think or wish they are.
Organisation & management	Internal-external (y)	Organisation managers	Other involved staff personnel	Organisational managers see their selves as more extern-oriented than others think or wish they are.
Averages per theme	Internal-external (y)	Actual Operation and maintenance managers	Empathised operation and maintenance managers	Operation and maintenance managers are more intern-oriented than others think or wish they are.
Average per theme	Internal-external (y)	Actual organisation managers	Empathised organisation managers	Organisational managers see their selves as more extern-oriented than others think or wish they are

8 | CONCLUDING DISCUSSION

In this paper, it was questioned whether serious gaming can create awareness about differences between the own preferred cooperative attitude and those of other responsible role-holders in flood defence management. To answer this question, a serious game Dike Dilemmas Under Pressure was designed taking into account requirements for such a game from theory and practice, such as providing value for the professionals and being a representative simulation of reality. The results of playing the game with multiple role-holders in flood defence asset management are analysed in terms of the game's capacity to enable better mutual understanding between the different roles and responsibilities within and between organisations involved in flood defence asset management.

Our study confirms that serious gaming creates awareness of the complexity and practice of others, one of the goals of serious gaming (Duke & Geurts, 2004). The participants' reflections indicate that the game urges them to take distance from their own roles and opinions, and to listen to and value others' argumentations. This created distance allows participants to experience the complexities of their colleagues' practices. The serious game supports the transformation of a group of individuals into a team of practitioners with mutual understanding.

Dike Dilemmas Under Pressure is applicable to provide awareness about differences in attitudes between role-holders or team members, within and between organisations. However, it does not provide insight into why these differences are present, or how to overcome these differences. Nevertheless, we observed an open mind in the reflection phase of the game about recognition of one's own and others' attitude, and its effect on cooperation. The serious game can be played several times during a project or in an organisation to monitor the degree of mutual understanding in the team.

Dike Dilemmas Under Pressure is developed as an online playable game. This hampers the possibilities of interaction between the participants, which is one of the characteristics listed in Table 1. This was solved by extending the game with a second game of two hours, allowing for in-depth discussions about an effective attitude and type of cooperation for a selected dilemma. The 'interactive feedback' (Table 1) is thus guaranteed in the game series.

Mirror plots are used to visualise the attitudes of the game players with respect to cooperation (internal/external and task/goal-oriented). Raters were involved to calibrate the positions in these plots. Statistical *t*-tests were conducted to evaluate significant differences in attitudes presented in the plots. Both the interrater agreement and the confidence interval in the *t*-tests are considered to be sufficient for this study, as the objective was to create awareness of differences between the own and others' attitudes. Whilst the outcomes provide an acceptably reliable insight for this study, more sessions can help to generate a more precise understanding of role-holder attitudes towards flood defence asset management dilemmas, which could be the focus of future research.

Dike Dilemmas Under Pressure provides a simple structured analysis of cooperating organisations or members of a team, enabling them to discuss attitudes, effects, and adaptations. It is set up for flood defence asset management. After the sessions, we often received the remark that it should be possible to apply the game design to other fields. We therefore heartily recommend this for subsequent research.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study is openly available.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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