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Serious gaming as an experiential learning tool: exploring the human–water perspectives in the case of Mt. Kenya water tower

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Diverse stakeholders in rural landscapes commonly have distinct and often conflicting needs and interests for the available water resources resulting in complex human-water interactions, especially in water-scarce regions. In such landscapes, resolving conflicting interests among individual viewpoints and moving toward collective human–water perspectives is paramount to achieving sustainable management of decreasing water resources. Serious games have been proposed as participatory tools for (social) learning in contested landscapes, however the impact of such approaches on learning is understudied. This study addresses this knowledge gap by evaluating the ENGAGE (Exploring New Gaming Approach to Guide and Enlighten) game as a tool for fostering collective human–water perspectives. The Upper Ewaso Ng'iro basin in Kenya was selected as the study area for its complex social-ecological dynamics, characterized by the interplay of climatic variability, competing water demands, and governance challenges that shape water resource management. Through five game sessions, participants' perspectives were assessed at three points in time: pre-game, post-game, and post-post-game, using the Q-method. Findings indicate that serious gaming enhanced awareness of catchment-scale water challenges, particularly the influence of geographic location, economic drivers, and illegal water abstractions on water availability. While immediate post-game assessments showed shifts in perspectives, long-term follow-ups revealed partial reversion to pre-game opinions, emphasizing the need for sustained engagement. This study contributes to the literature on complex human–water interactions by demonstrating the potential of serious gaming in promoting experiential learning and stakeholder engagement in water governance. The findings are relevant for socio-hydrological scientists, water resource managers, and policymakers seeking innovative approaches to conflict resolution and sustainable water management.

KEYWORDS

experiential learning, human–water perspectives, pre–post-game tests, Q-method, game impact assessment

1 Introduction

Sustainability of water resources is perhaps the most emotive topic in water-scarce regions. Within river catchment, people tend to have conflicting interests and perceptions that influence how they interact with their physical environment to reap maximum benefits from it (Wallace et al., 2003; Peters et al., 2023). Along the upland–lowland landscape gradient of a river catchment, variations in rainfall and atmospheric energy and land-use distinctions influence water resources availability within the catchment (Näschen et al., 2019; Martins et al., 2021). Within the same gradient, stakeholders can differ in a variety of ways including culture, livelihoods, perspectives, and attitudes on human-water interactions. Water availability dynamics is one key factor that influences human behavior as people (who largely depend on it) adapt to changing hydrological conditions (Garrote, 2017; Pande et al., 2020). Competition for available water resources can lead to water-related tensions and even conflicts between downstream and upstream communities, and households (Wamucii et al., 2023). Conflicting stakeholders' perspectives on water resources lead to complex human–water interactions as different stakeholders, depending on their unique water needs, have independent demands and interests for available water resources (Renner and Opiyo, 2021). As a result, competing water demands among households and between humans and the environment exist. Resolving conflicts of interest among individual viewpoints toward collective perspectives is paramount to achieving sustainable management of water resources in a water-scarce environment (Molnar et al., 2017; Bernauer and Böhmelt, 2020). Therefore, it is relevant to study the approaches and methodologies that have the potential to promote collective understanding among diverse stakeholders.

Differences in culture, individual values, and preferences are key to the way societies perceive, interact, use, and manage water resources (Grafton and Hussey, 2011; Cosgrove and Loucks, 2015; Loucks and van Beek, 2017; Dadson et al., 2019). Sustainable management of water resources requires an integrated approach to managing and allocating water resources, by accounting for stakeholders' divergent socio-hydrological perspectives and values (Di Baldassarre et al., 2019). Cumming et al. (2006) highlighted that many challenges in natural resource management arise from a mismatch between the scale at which management occurs and the scales of the underlying processes. This misalignment is evident in water resource management, where the increasing demand for water has significantly outpaced population growth. For instance, Cosgrove and Loucks (2015) reported that, in recent decades, the global rate of water use has increased at more than twice the rate of population growth, leading to widespread water stress. With the uncertain future effects of changing climate, demographics, technological dynamics (Moss et al., 2010), there is a pressing need to purposively explore alternative approaches to managing human–water processes. Such approaches should have the ability to simulate the outcomes of conflicting human viewpoints of various stakeholders in a safe environment. This is needed to explore possible outcomes in ways that can develop valuable lessons for diverse stakeholders, hence the inclination towards collective understanding.

Achieving shared perspectives in ways people view and interact with their environment is complex due to differences in the humans' mental models (i.e., perspectives) that proliferate "wicked" problems. This research adapts the definition of mental models as the cognitive representations of the social-environmental system that frames how humans interact with their environment (Mathevet et al., 2011). Q-method has gained popularity as a key approach for evaluating stakeholders' perspectives (Bavin et al., 2020; Dieteren et al., 2023). Scientific research is vital for addressing complex problems, but its interpretation is often limited to professionals, excluding key stakeholders like small-scale farmers, who rely more on reflective learning and personal experiences (Kuil et al., 2018). Thus, a need for alternative approaches that can enhance learning from experience. Alternative participatory approaches such as serious games offer the opportunity for reflective and experiential learning (Pannese et al., 2013; Ponticorvo et al., 2022). Serious gaming refers to the use of games for purposes beyond pure entertainment, such as education, training, awareness creation, or social change (Dahya, 2009; Smith and Bowers, 2014; Savic et al., 2016). These games are designed to engage users while delivering meaningful content or helping them develop specific skills in a fun and interactive way (Dillon, 2013; Noemí and Máximo, 2014). Serious gaming encourages team-based problem-solving and addresses typical conflicts of interest (Kikkawa et al., 2022). Interacting with virtual systems such as board games presents a suitable learning platform for both professionals and non-professionals. Potential collective agreements and actions can be explored through interaction in collaborative and participatory settings (Pahl-Wostl et al., 2007; den Haan and Van der Voort, 2018; Kikkawa et al., 2022).

Recent studies report serious gaming as an alternative participatory approach that facilitates discussion and promotes experiential learning among diverse stakeholders, hence supporting collective future planning (Speelman et al., 2014; Meinzen-Dick et al., 2018; Andreotti et al., 2020; Best et al., 2021; Mochizuki et al., 2021). Experiential learning occurs when stakeholders generate new knowledge or a change in understanding or perspectives through a process of experience, experimentation, and reflection which will lead to adjusted or new perspectives (Speelman et al., 2017; Janssen et al., 2023). The effect of serious gaming on stakeholders' perspectives can be evaluated by conducting pre–post-game tests (Goodspeed et al., 2020; Salliou et al., 2021; McConville et al., 2023). The gaming workshops supports exploring the impacts of local decisions, hence exploring potential and different human–environmental systems scenarios. We hypothesize that the gaming process, particularly through the use of board games, provides a structured and interactive platform for experiential learning, allowing stakeholders to engage in simulated decision-making processes that foster deeper insights into complex socio-environmental interactions.

Despite the growing interest in the use of serious games as an alternative participatory approach among researchers and practitioners (Wesselow and Stoll-Kleemann, 2018; Rodela et al., 2019; Rodela and Speelman, 2023; Speelman et al., 2023), there remains limited information on the impact of this gaming approach in increasing knowledge and understanding among the targeted stakeholders (Rodela and Speelman, 2023). Prior studies have not extensively examined how serious gaming influences stakeholders' knowledge, attitudes, and discourse on water resource challenges over time. By employing the Q-method to analyze shifts in stakeholder perspectives pre- and post-game, this study provides empirical insights into the effectiveness of serious gaming in fostering experiential learning and collaborative decision-making. The Q-method has been employed to explore discourse changes, including comparing multiple Q outcomes (Davies and Hodge, 2012; Speelman et al., 2018) and evaluating stakeholders' views across different locations (Zhou and Mayer, 2017). The initial explorations utilizing the Q-method approach to assess the potential impact of serious gaming, based on pre- and post-game session perspectives, indicated promising results (Speelman et al., 2018).

This study aimed to explore the impact of serious gaming on human–water perspectives. The upper Ewaso Ng'iro River catchment in Kenya was selected as the case study due to its complex socio-ecological system. We conducted five game sessions using the ENGAGE game—Exploring New Gaming Approach to Guide and Enlighten (Wamucii et al., 2024). To understand the impact of the gaming session on the perspectives of the game participants, the pre-game, post-game, and post-post-game assessments were conducted using the Q-method approach (Watts and Stenner, 2005; Watts and Stenner, 2012; Amaruzaman et al., 2017). The key question to be answered in this study is: How do stakeholders' perspectives on human–water interactions evolve over time as a result of participating in the ENGAGE serious game, and to what extent do these changes persist post-game?

2 Methodology

2.1 The study area

The study area is situated within the upper Ewaso Ngiro River basin, located northwest of the Mt. Kenya forested water tower, approximately 180 km north of Nairobi (between 0.14° N and 0.09° S latitude, and between 37.03° E and 37.28° E longitude). The basin spans a notable climatic gradient, with the upstream zone receiving an average annual precipitation of 1,500 mm, characteristic of its humid climate, while the downstream zone experiences a markedly drier environment with only 350 mm of annual precipitation (Wamucii et al., 2023). This climatic variation profoundly influences land use, water availability, and local livelihoods.

The upstream and midstream zones of the basin are predominantly characterized by both small-scale and large-scale agricultural activities (Wamucii et al., 2023; Wamucii et al., 2024). These agricultural systems rely heavily on water resources for irrigation, with the area hosting various crops such as maize, horticultural products, and other subsistence crops. Conversely, the downstream areas are more arid and are dominated by pastoralism, where livestock farming, particularly cattle, forms the backbone of the local economy. Wildlife-oriented tourism is also a key economic activity in the downstream region, with the area's natural biodiversity drawing both local and international tourists. These diverse land-use activities underscore the varying demands on water resources throughout the basin (Wamucii et al., 2024).

Water resources in the study area are managed by community-based Water Resources Users Associations (WRUAs), which play a crucial role in regulating water use and managing conflicts over water allocation. WRUAs are challenged by the increasing demand for water due to population growth, agricultural expansion, and climate variability, along with limited enforcement of water abstraction regulations, thus strained the system and intensified conflicts (Wamucii et al., 2024).

The downstream effects of upstream water abstraction are significant, as water used for irrigation and domestic consumption upstream reduces the flow in the river downstream, exacerbating water scarcity in the arid regions (Wamucii et al., 2024). These altered hydrological flows have created tensions between upstream and downstream water users, with the downstream communities experiencing significant water shortages during dry seasons. Water-related conflicts have become increasingly violent, driven by competition for limited water resources, highlighting the lack of awareness among upstream communities of the broader downstream impacts of their activities (Wamucii et al., 2023).

The study area presents a complex socio-ecological system, where climatic, hydrological, and human factors intersect, creating both opportunities and challenges for sustainable water resource management. To address these complex challenges, exploring participatory alternatives, including serious games to enhance stakeholder engagement, is deemed timely. The game participants were drawn from five sub-basins representing the interests and perspectives from the upstream, midstream, and downstream zones of the catchment.

2.2 The serious game and participants

This study focused on evaluating stakeholders' perspectives, during pre-game, post-game, and post-post-game. In addition to Q-method, post-game individual interviews and stakeholder debriefings were conducted with game participants to understand the key lessons learned from the gameplay. The serious game known as ENGAGE-v1 as conceptualized and applied in Wamucii et al. (2024) was adopted in this study. ENGAGE is a board-based role-playing game designed to enhance collaborative decision-making and experiential learning in river basin management. The game involves ten participants representing upstream and midstream agricultural communities, downstream pastoralists, a local water regulator (WRUA), and the national government. The game participants aim to maximize profits while minimizing water-related conflicts, simulating dry-season water dynamics in the upper Ewaso Ng'iro catchment using marbles to represent water flow along a river network. The game begins under a "normal" climate scenario and transitions to variable conditions influenced by a dice roll, reflecting climate variability. Gameplay occurs in two phases: an initial phase where participants act based on individual values and preferences, and a reflection phase encouraging collective discussion on potential solutions to observed human–water challenges. Typically played in four rounds over 2.5 h, the structured game evolves to incorporate agricultural land expansion, fostering insight into the complexities of water resource management. The game description summary is provided in Table 1.

2.3 Formulating hypothesis and Q-statements

Q-methodology is a research technique that focuses on exploring the diversity of opinions among different stakeholders, offering a clear and structured approach to understanding subjective viewpoints (Watts and Stenner, 2012). This semiquantitative, mixed-methods approach integrates both qualitative and quantitative elements,

TABLE 1 Game description (summarized from Wamucii et al., 2024).

Name of the game: ENGAGE_v1 – "Exploring New Gaming Approach to Guide and Enlighten" ENGAGE is a type of Board plus role-play game that seeks to increase collaborative decision-making in the river basin through experiential learning. The goal of the game is to engage and stimulate discussions and learning among participants. There are a total of ten active game participants per game session: - 2 participants representing the upstream agricultural community - 4 participants representing the midstream agricultural community - 2 participants representing the pastoralists in the downstream zone - 1 participant plays the role of implementing local water regulations (i.e., WRUA) - 1 participant plays the role of the national government (imposing rules and fines). The declared individual goal for the eight land-user participants is to win a game round by accumulating the largest sum of money (profits) at minimal water-related conflicts. The ENGAGE game mimics the dynamics observed during the dry seasons in the upper Ewaso Ng'iro catchment. The river network (i.e., marbles on boardgame) connects the communities as water flows from the forested Mt. Kenya water to the downstream areas. In the first round, participants play the game under an assumed "normal" climate scenario (i.e., with a maximum of 100 marbles). In the subsequent rounds, a dice is used to determine the exogenous conditions and hence the number of marbles to be placed on the board game (i.e., ranging between 70 and 100 marbles). There were two phases in the implementation of the ENGAGE game in this study. Phase one mimics reality, whereby individual values and preferences of the game participants were allowed to shape the game results. The first two or three rounds were considered sufficient for game participants to learn from individual decisions and consequences. In the second phase (i.e., a final round or "reflection" round), the game participants were guided to reflect on the game results and experiences in phase one and think objectively about what could be the potential solutions to the human–water challenges observed in phase one. There are no maximum rounds of the ENGAGE game, game participants can continue playing as long as they are willing. However, four rounds were considered sufficient given the time factor which averaged 2.5 h per game session in each sub-catchment (i.e., after four rounds). The ENGAGE game as implemented in this study was relatively closed and strictly followed the rules set out in Wamucii et al. (2024). The rules remained relatively the same in all game rounds apart from the agricultural lands expansion that evolved in the succeeding game rounds. More information about the conceptualization and application of the ENGAGE game is given in Wamucii et al. (2024).

enabling researchers to systematically capture the complexity of individual perspectives across a wide range of fields, such as applied linguistics, social justice, and environmental management. By emphasizing participant reflexivity and engagement, Q-methodology is particularly effective for addressing nuanced issues (Zabala et al., 2018). Key features of Q-methodology include the exploration of subjectivity (O'Shea, 2024), the Q-sorting process (Seghezzo et al., 2024), and the integration of qualitative and quantitative insights (Parry, 2022).

Given a diversity in opinions on a variety of human–environmental issues, Q-method can be used to categorize the individual viewpoints into clusters of value positions, belief systems, or mental model (McKeown and Thomas, 2013; Zabala et al., 2018). In order to formulate relevant Q-statements, existing human–water perceptions were sourced from the literature, key informant interviews (seven WRUAs and five representatives from water authority (WA) and local organizations), and seven focus group discussions with the local communities in each sub-basin within the study area. When formulating the Q-statements, the study focused on identifying the major human-water issues that are believed to cause water shortages and conflicts during dry seasons in the upper Ewaso Ng'iro basin. Out of the many issues gathered, the authors narrowed down to 16 Q-statements (Table A1) that were crosscutting in all the sub-basins within the study catchment. A 16 Q-sort grid design was developed as shown in Figure A1. The Q-sort cards with pictures and translated in Swahili (Figure A2) were used in five game sessions and presented to the game participants pre-game, post-game, and post-post-game Q-sort sessions.

2.4 Q-sort assessments

A total of 40 participants were involved in pre and post-game assessments, and 32 participants in the post-post-game assessment. Before the start of the game (i.e., pre-game), the game participants were presented with the 16 Q-statements and the 16 Q-sort grid. A Q-sort grid is a pivotal component that enables participants to systematically rank statements based on their subjective opinions, facilitating the organization and analysis of qualitative data (Kumar et al., 2023). Participants were first requested to arrange the Q-sort cards into three piles of agreement, which is; agree, neutral, and disagree. Starting with either agree or disagree, the participants were further requested to sort each pile so that all the 16 Q-sort cards were placed on the Q-sort grid. The grid had a scale ranging between −3 and + 3 (Figure A1). The participants were allowed to read the Q-statements and make decisions on where to place the cards on the grid. In most cases, the participants independently interpreted the Q-statements, however, the facilitator was available to guide the process and assist participants who required help. The Q-sort exercise was also repeated immediately after the game session (i.e., post-game). A debriefing session was also conducted after the post-game Q-sort to discuss game experiences with participants. Debriefing provides game participants with an opportunity to share multiple perspectives and construct common mental models (Kikkawa et al., 2022). After several months, and specifically at least three months (i.e., a period that has a transition from the wet season to the dry season) after playing the game, a post-post-game Q-sort exercise was conducted. The same game participants were invited and subjected to the same 16 Q-statements presented to them during pre-post-game sessions. Note that there was no playing the ENGAGE game during post-post-game Q-sort sessions. This was important to evaluate whether the perspectives observed at the end of the game prevailed beyond the game environment. Table 2 shows the period in months of post-game Q-sort exercise for the five sub-basins.

2.5 Q-sort analysis

The collected Q-sorts were analyzed with *KenQ Analysis* Desktop Edition (*KADE*) version 1.2.1 (Banasick, 2019). KADE correlates the Q-sorts data, resulting in correlation matrices (Psiuk, 2022). This study defined the diversity of opinions based on the factors, which are defined as clusters of shared perspectives (Psiuk, 2022). The extraction of typically two to four factors (Lundberg et al., 2020;

TABLE 2 The period between the actual game session and the post-post-game Q-sort exercise.

Game session	Number of months since serious game session
Ngusishi game session	7 months
Nanyuki game session	6.5 months
Likii game session	7 months
Sirimon game session	5 months
Ontulili game session	5 months

Morea, 2022) from a Q-sort data analysis is a key step in the Q study. KADE tool can give up to a maximum of eight unrotated factors, which are automatically calculated from the Q dataset. In this study, four criteria were used to determine the number of factors to be extracted: (i) The scree plot visual analysis, where the index of the last factor is visually determined before the plot flattens (Donald et al., 2009; Hubert, 2009), (ii) the Kaiser-Guttman criterion which states that only factors with an Eigenvalue (EV) greater than one should be retained (Zabala et al., 2018; Ihemezie et al., 2022; Bayala, 2023), (iii) the explained variance, where the total explained variance of factors retained must exceed 50% of the total variance and each factor retained accounts for at least 10% of the total variance (Sneegas et al., 2021) and (iv) the "Humphrey-strict" rule, where the cross product of two highest loadings exceeds twice the standard error (Banasick, 2020).

Since no single extraction criterion can determine the best factor solution (Auerswald and Moshagen, 2019), the factor number with the highest frequency (across the four criteria) was selected in this study. In case of no frequency, the lowest number would be considered as it is assumed these are the factors with the most representative and unique qualities (i.e., the largest variance in the study). Principle component analysis and varimax rotation were applied to the extracted factors (Banasick, 2019; Banasick, 2020). Varimax rotation is a criterion for analytic rotation commonly used to transform factor loadings to a pattern that is easier for inspection and interpretation (Wu, 2014). After factor extraction, the final step was to interpret the extracted factors, which was based on the ranking of statement scores in each factor and the identification of distinguishing statements for each factor (Hermans et al., 2012; Zabala et al., 2018; Akhtar-Danesh and Wingreen, 2022). In this study, the labeling of each factor (herein referred to as opinion type) was based on the highest positively ranked statement at significance ($p < 0.01$). Consensus in the opinions was evaluated by determining factors revealing similarities the ranking of different Q-statements. Diversity in opinions was determined by selecting statements with Z score variance above a value of 1. This value was selected as an arbitrary value for cross-comparison in the different Q-sort sessions. A Sankey diagram was used to visualize the factors in the three moments of time (pre-game, post-game, and post-post-game). A Sankey diagram is a specialized flow diagram used to visually depict the movement of elements within a system (Schmidt, 2008; Lehrman, 2018). Its defining characteristic is the proportional width of the arrows (or flows), which accurately represents the quantity of the elements, their distributions and trends. In this study, the Sankey diagram was developed by first compiling data in an Excel file, which was subsequently imported into the Visual Paradigm online platform (Visual Paradigm, 2023).

3 Results

3.1 Extracted factors and their characteristics

There were four factors extracted in each of the Q-sort data (pre-game, post-game, and post-post-game) based on the set-out criteria in subsection 2.4 above (Table 3). The most differentiating statements in the factors both positively and negatively ranked, and the highest and lowest ranked statements were used to interpret the type of opinions that emerged in the different Q-sort sessions. The different factors in the different Q-sort sessions are described below. The summary characteristics of the extracted factors are listed in Table A2.

3.1.1 Opinion types identified in the pre-game sessions

Four opinion types were identified in the pre-game Q-sort sessions. The unique differences in the four opinion types are described below.

3.1.1.1 Pre-game opinion type 1: "agricultural land blamers"

This opinion type is characterized by a strong agreement that increasing agricultural land contributes highly to excessive river water abstractions. There was also agreement that rainwater harvesting is an important activity. However, this opinion type disagrees that the increasing market opportunities in the catchment (e.g., export companies) encourage more farmers to increase crop production, hence encouraging more river water abstractions. There was also a disagreement with the statement that increasing water crises during dry seasons is a result of ineffective water governance and management in the catchment.

3.1.1.2 Pre-game opinion type 2: "corruption blamers"

This opinion type is characterized by linking corruption in water resources management to ineffective control of river water abstractions. There was also agreement that water shortages experienced during dry seasons are a result of more farmers responding by intensifying irrigation activities. However, in this opinion type, rainwater harvesting was not rated as an important activity that can reduce pressure on scarce water resources during the dry season.

3.1.1.3 Pre-game opinion type 3: "urban towns blamers"

This opinion type is characterized by a strong agreement that the growing urban towns within the catchment affect water demand, hence the reduced river flows. There was also agreement on rainwater harvesting as an important activity. There was a disagreement with the statement that illegal river water abstractions are major contributors to the water shortages in the catchment.

3.1.1.4 Pre-game opinion type 4: "market prospects blamers"

This opinion type is characterized by a strong agreement that the increasing market opportunities in the catchment (e.g., export companies) encourage more farmers to increase crop production, hence more river water abstractions. Similarly, to opinion types 1 and 3, rainwater harvesting was ranked as an important activity. There was

TABLE 3 The number of factors extracted.

Q-sort sessions	No. of factors based on Scree plot visual analysis	No. of factors based on eigenvalues >1	No. of factors based on total explained variance	No. of factors based on the 'Humphrey-strict' rule	No. of factors extracted
Pre-game	4	8	4	5	4
Post-game	4	8	4	4	4
Post-post-game	3	8	4	4	4

also agreement that the study catchment is located on the leeward side/drier side of the Mt. Kenya water tower, and this contributes to the water shortages observed during the dry season. There was also agreement that the pastoralist communities increase their livestock numbers to boost their wealth, hence the greatest suffering observed in the downstream zone during dry seasons. This opinion type, however, disagrees that during dry seasons, pastoralist communities react by migrating their animals to the upland areas in search of water, which leads to water-related conflicts.

3.1.2 Opinion types identified in the post-game sessions

Four opinion types were also identified in the post-game sessions. The unique differences in the four opinion types are described below.

3.1.2.1 Post-game opinion type 1: "water governance blamers"

The most distinguishing statement in this opinion type is the strong agreement that there is ineffective governance and management of water resources in the catchment, which has contributed to human–water crises during dry seasons. There was also agreement in this opinion type that uncertainty in climate change has a major effect on water resource availability. This opinion type disagrees that the growing human population increases the number of abstraction points and hence the reduced river flows. There was also disagreement on the statement that more farmers react to dry seasons by intensifying irrigation activities, which contributes to water shortages in the catchment.

3.1.2.2 Post-game opinion type 2: "urban towns blamers"

The most distinguishing statement in this opinion type was the strong agreement that the growing urban towns play a big role in reducing the river flows. Similarly to opinions identified in opinion type 1, this opinion type concurs with the agreement that uncertainty of climate change has a major effect on catchment water resource availability. However, in this opinion type, there was disagreement with the statement that pastoralist communities react to dry seasons by migrating their livestock to the upland areas in search of water, which contributes to water-related conflicts.

3.1.2.3 Post-game opinion type 3: "pro-rainwater harvesting"

This opinion type was characterized by highly-ranking water harvesting as an important activity that can reduce pressure on scarce water resources during the dry season. Additionally, in this opinion type, there was agreement that catchment aridity increases the susceptibility of the pastoralist communities during dry seasons. However, there was disagreement that uncertainty in climate change has a major effect on water resource availability. There was also a disagreement with the statement that the increasing water crises in the catchment are a result of ineffective water governance and management.

3.1.2.4 Post-game opinion type 4: "livestock blamers"

The opinion type was highly characterized by the strong agreement that the increase in livestock numbers among pastoralists contributes to the greatest suffering observed in the downstream zone during dry seasons. There was disagreement with the statement that the conversion of natural vegetation to agricultural lands is a major contributor to the reduction of river flows in the catchment. The opinion type revealed disagreement that corruption is an issue in water resources management.

3.1.3 Opinion types identified in the post-post-game sessions

Four types of opinion types were also identified during the post-post-game Q-sort sessions. The unique differences in the four opinion types in the post-post-game sessions are described below.

3.1.3.1 Post-post-game opinion type 1: "huge profits blamers"

The opinion type is characterized by a strong agreement that huge profits from dry-season crops encourage more farmers to abstract river water during dry seasons. This opinion type agrees that water scarcity problems can be linked to the increase in area under agricultural land and farmers intensifying irrigation activities during dry seasons. However, there was disagreement with the statements on corruption and ineffective water governance and management in the catchment.

3.1.3.2 Post-post-game opinion type 2: "climate change blamers"

This opinion type is characterized by a strong agreement that uncertainty in climate change has a major effect on the catchment's water resources availability. There was also agreement that the conversion of natural vegetation to agricultural lands is a major contributor to the reduction of river flows. This opinion type also agrees that the catchment aridity increases the susceptibility of pastoralist communities during dry seasons. However, there was disagreement with the statement that the growing human population in the catchment plays a key role in increasing the number of abstraction points. Similarly, to opinion type 1 above, there was a disagreement with the statement on ineffective governance and management of water resources in the catchment.

3.1.3.3 Post-post-game opinion type 3: "urban towns blamers"

The most distinguishing statement in this opinion type is the agreement that the reduction of river flows is a result of growing urban towns. There was also agreement that converting natural vegetation to agricultural lands is a major contributor to reducing river flows. There was disagreement with the statement that water-related conflicts during dry seasons are a result of the pastoralist communities' reacting by migrating their animals to the upland areas in search of water.

3.1.3.4 Post-post-game opinion type 4: "corruption blamers"

This opinion type is characterized by an agreement that corruption in water resources management impacts the control of river water abstractions. However, there was disagreement with the statement that the conversion of natural vegetation to agricultural lands is a major contributor to the reduction of river flows in the catchment.

3.2 Overall ranking, consensus, and diversity in opinions

The consensus in the pre-game sessions was observed in statement 1, that uncertainty in climate change has a major effect on water resource availability. Another consensus was a disagreement with statement 8, that huge profits from crops grown during dry seasons, encourage more river water abstractions. There was also a consensus in disagreeing with statement 15, that river basin organizations are unable to effectively govern and manage water resources (Figure 1A). The statement with the most diversity in opinion in the pre-game session was statement 3, that rainwater harvesting is an important activity (Figure 1A).

In the post-game sessions, a consensus was observed in statements 7 (market prospects) and 8 (huge profits). The four opinion types disagreed that the increasing market opportunities in the catchment (e.g., export companies) encourage more farmers to increase crop production, hence more river water abstractions. There was also disagreement that huge profits from crops grown during dry seasons, encourage more farmers to abstract river water during dry seasons (Figure 1B). The statements with the most diversity in opinion were statements of uncertainty in climate changes (statement 1), rainwater harvesting (statement 3), and livestock numbers (statement 9) (Figure 1B).

In the post-post-game sessions, the common similarity in the four opinion types was a shift in the perspectives whereby there seemed to be a consensus that the increasing market opportunities in the catchment (e.g., export companies) encourage more farmers to increase crop production, hence more river water abstractions (Figure 1C). Another consensus was a disagreement that the increasing water crises during dry seasons were a result of ineffective governance and management of water resources in the catchment. The results indicate that there were more statements with high diversity in opinions in the post-post-game sessions including conversion of natural vegetation (statement 4), huge profits (statement 8), urban growth (statement 11), livestock migration (statement 13), and corruption (statement 16) (Figure 1C).

Comparing the Z score variances of the pre-game and post-game sessions, the ENGAGE game seemed to have created a consensus on statement 2 (catchment location), 7 (market prospects), and statement 14 (illegal water abstractions). However, the results also revealed that after the game sessions, there was an increase in Z score variance in statements 1 (uncertainty on climate change) and 9 (livestock numbers) (Figure 2A). Comparing the Z score variances of the post-game and post-post-game sessions, there were more statements showing a decrease in Z score variance, that is, statements 1, 3, 9, 12, and 15 (Figure 2B). More statements with an increase in Z score variance were also observed during the post-post-game Q-sort sessions such as statements 4, 8, 13, and 16. The potential impact of the ENGAGE game beyond the game environment can be illustrated with maintained consensus (low Z score variance) for statements 2, 7, and 14. The disagreement on these three statements was reduced immediately after playing the game and a maintained consensus can be observed both in the post-game and post-post-game sessions.

The study results also reveal that statements on land use and population issues were not as volatile compared to other statements. For instance, in all the Q-sort sessions (pre-game, post-game, and post-post-game), there were relatively low changes in the Z score variance for land use issues such as the conversion of natural vegetation (statement 5), increase in agricultural lands (statement 6), and human population growth issue (statement 10).

3.3 The mapping of opinion types in the different Q-sort sessions

The changes in opinion types in the different Q-sort sessions were analyzed using a Sankey diagram (Figure 3). The pre-post-game evaluation revealed that the pro-rainwater harvesting opinion type, an opinion that emerged immediately after the ENGAGE game sessions, was mainly loaded by participants who had initially loaded into agricultural land blamers and corruption blamers in the pre-game sessions. In the post-post-game session, the results indicate that most participants who had loaded to water governance blamer's opinion shifted their opinions to huge profits blamers. The most intriguing result is that the "pro-harvesting opinion type" only appeared after the ENGAGE game sessions going by the majority of participants (33%), while most of the other opinion types were labeled with the "blamers" label (Figure 3). However, the pro-harvesting opinion type disappeared after several months and participants were observed to shift their opinions to climate change blamers and urban towns blamers. The results also indicate that the opinion type on "urban town blamers" emerged in all Q-sort sessions (i.e., pre-, post, and post-post-game sessions), although loaded by different participants who were switching from different types of opinions in each of the sessions.

3.4 Key lessons based on post-game interviews and debriefings

The post-game debriefings revealed that the most cross-cutting lessons for the ENGAGE sessions mentioned by all game participants included: (1) importance of water storage, (2) the value of collective stakeholder engagements, (3) importance of effective water resources management, and (4) fair sharing of water resources (Figure 4). The common lessons mentioned between upstream and midstream game participants include: the game revealed a need to change

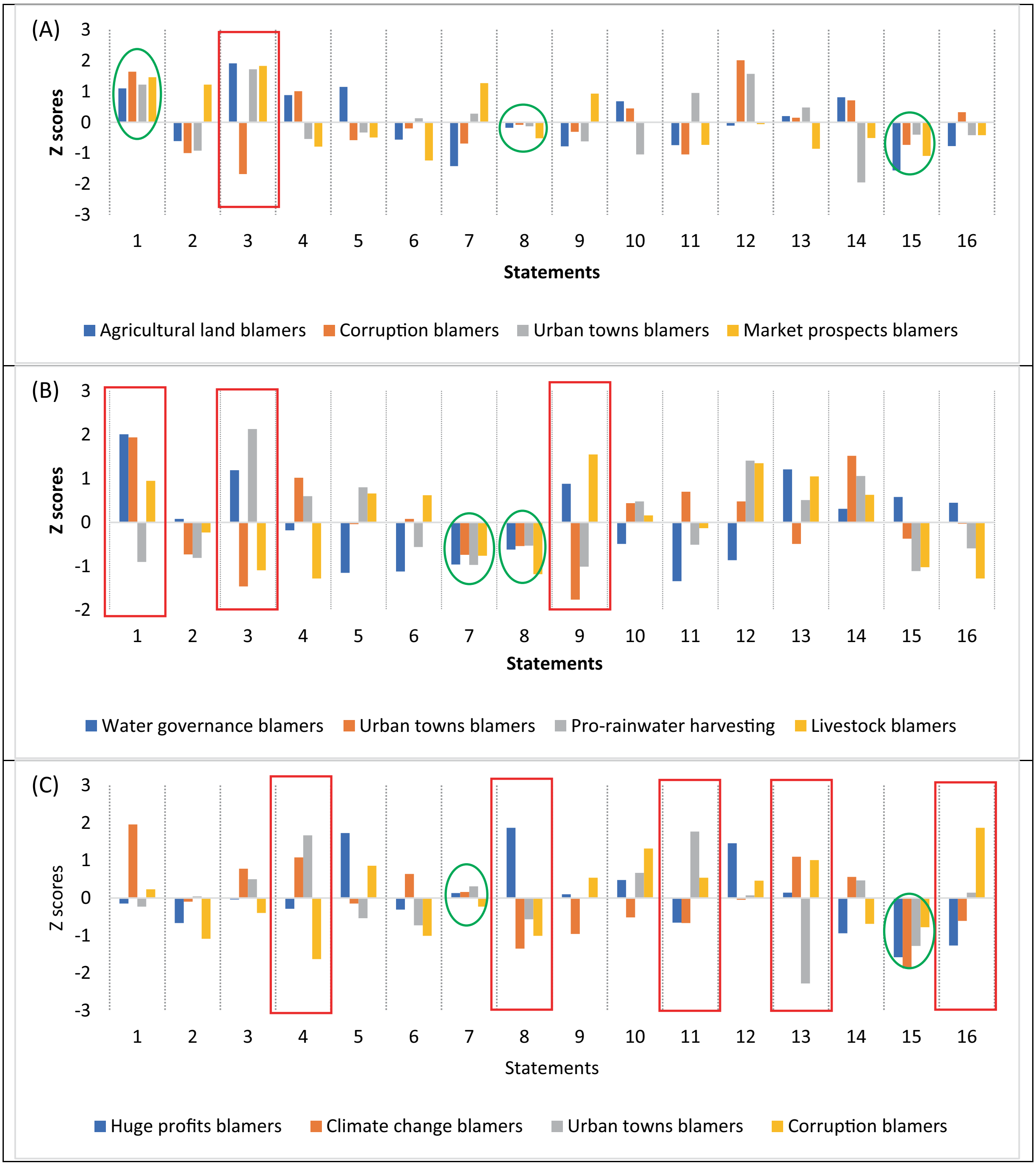

FIGURE 1
Opinion types Z score ranking in the pre-game **(A)**, post-game **(B)**, and post-post-game **(C)** sessions. The green rings indicate the consensus statements at $p < 0.05$. The red box indicates the most disagreed statements with a Z score variance above a value of 1—an arbitrary value used for cross-comparison. The Z score variances are shown in Figure 2.

high-water-demanding farming practices, efficient irrigation methods, and importance of collective/community approaches in addressing water scarcity problems. The common lesson mentioned between the midstream and the downstream game participants was that the game reminded them that the solution is not in fighting or blaming shifting. The common lessons mentioned between the upstream and downstream game participants include: a need for upstream people to consider downstream people, and that it is possible to find feasible solutions to reverse downstream water scarcity.

Besides, the after-game interviews revealed more specific lessons for participants from the different parts of the catchment. For instance, the upstream participants reported that the game helped them to reflect and learn that they have a role to play concerning decreasing downstream flows, the need for water conservation, and information on environmental degradation processes. The midstream participants

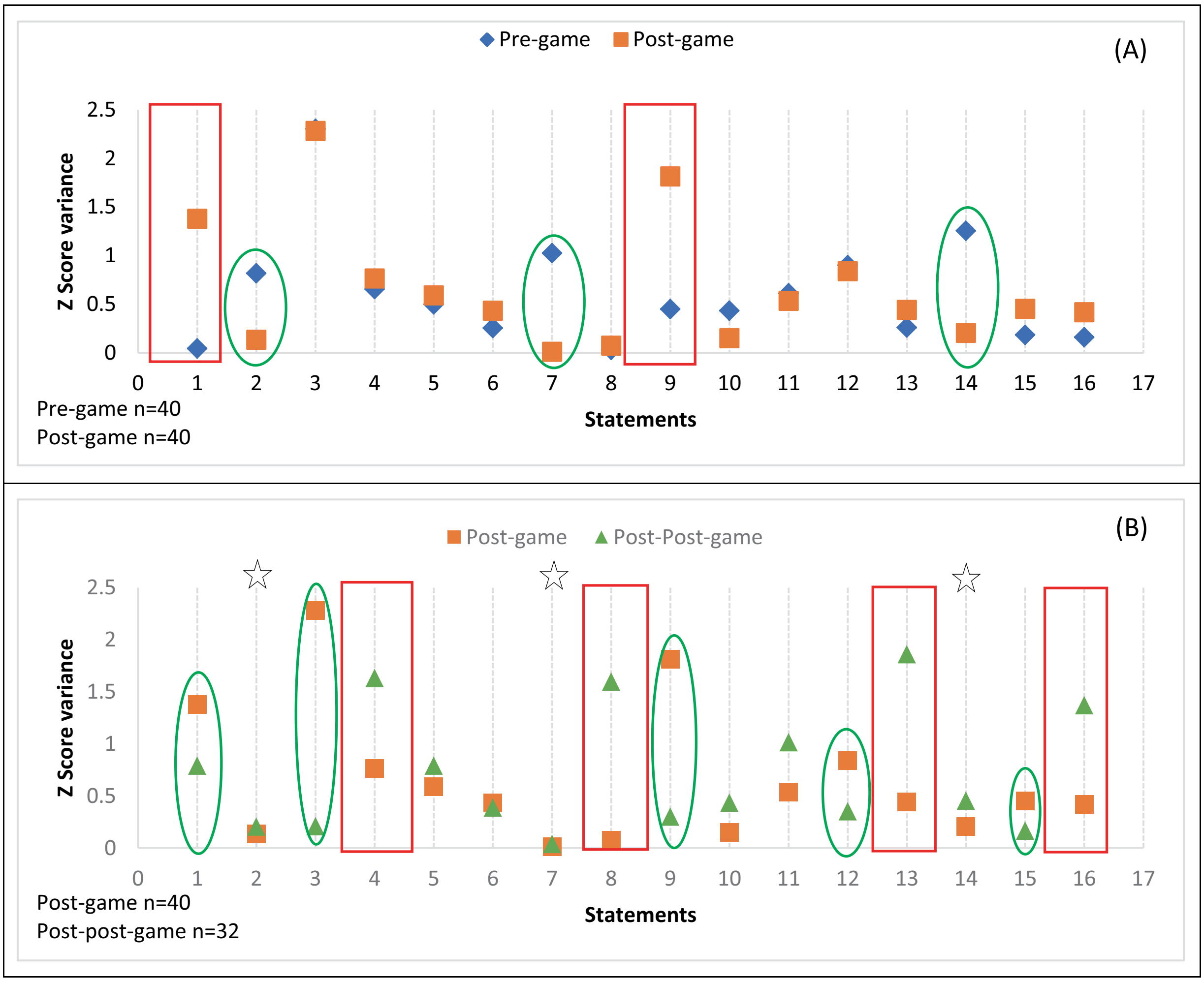

FIGURE 2
Cross-comparison of Z score variance, between pre-game and post-game **(A)**, and between post-game and post-post-game **(B)**. The green rings indicate statements where Z score variance is reduced (consensus). The red boxes indicate the statements where Z score variance increased (disagreement). The stars in B indicate statements where a consensus was constructed after the ENGAGE game and maintained throughout for several months (i.e., observed during post-post-game sessions).

reported how the game informed them on how to manage scarce water resources during dry seasons, river water conservation, and the benefits of collective approaches. The downstream participants reported that the game helped them realize that overstocking increases pressure to existing water scarcity problems, and the importance of government support.

4 Discussion

This study aimed to assess the impact of actively participating in a serious gaming session on the human–water perspectives of game participants. We used the Q-method to assess and compare the perspectives of the game participants at three moments in time, namely pre-game, post-game, and post-post-game. The overall results show different opinions emerging in the pre-game, post-game, and in the post-post-game Q-sort sessions. In the pre-game sessions four opinion types that were more oriented to agreeing with hydrological issues such as climate change and rainwater harvesting and disagreeing with the negative impact of "profit-making" emerged. In the post-game sessions, four opinion types that were more oriented to disagreeing with catchment economics but agreeing on the negative impacts of illegal river water abstractions emerged. In the post-post-game Q-sort sessions, four opinion types that indicated a change in pre-game perspectives on the negative impacts of catchment economics on water resource availability variations emerged. The differences in opinion types in three different moments in time suggest potential learning of the stakeholders to change standpoints. We argue this could have been influenced by experiential learning during gameplay which concurs with other similar opinions (López-Faican and Jaen, 2021; Parakh et al., 2022; Pacheco-Velazquez et al., 2023). Assuming perspectives observed in the pre-game sessions can represent the pre-game discourses or conventional perspectives, then, the observed changes in the post-game sessions can be linked to experiential learning from the ENGAGE game.

During gameplay, players are triggered to make individual decisions relative to the interests of others and of the collective. The game experience stimulates experiential learning while by sharing

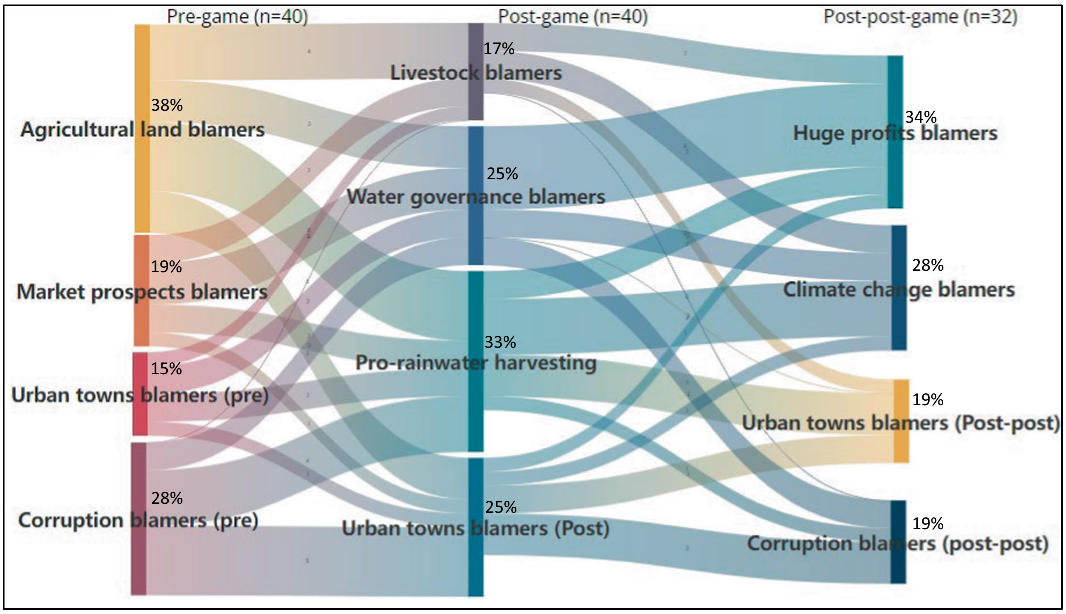

FIGURE 3
A Sankey diagram showing the changes in opinion types in the different Q-sort sessions. Design based on Visual Paradigm (2023).

knowledge, opinions and ideas among the group of participants also collaborative learning is fostered. Key aspects of the gameplay can be connected to the factors that make learning experiences and outcomes more accessible, memorable, emotionally engaging, and shareable as opined in Sereenonchai and Arunrat (2024). For instance, the immediate and simultaneous observation of outcomes ensured that learning was accessible, as participants shared real-time decision-making experiences that were transparent and easily understood, creating a common ground for reflection and discussion. The realistic scenarios simulated during gameplay, such as resource scarcity, competition, and negotiation, along with the visible and tangible consequences of decisions, made the learning process memorable and the lessons more likely to be retained. Emotional engagement was heightened through conflicts, particularly between downstream and upstream game participants over reduced water resources, as participants had to navigate the tension between individual interests and group needs. This combination of conflict and cooperation drove deeper learning and engagement. The collaborative nature of the game further enhanced shareability, as participants exchanged knowledge and collectively synthesized their experiences during the reflection round, creating narratives that could extend beyond the gameplay itself. As reported in Wamucii et al. (2024), the ENGAGE game significantly enhanced narratives through active participation. Additionally, the iterative rounds provided opportunities for game participants to adapt their strategies based on observed outcomes, promoting behavioral insights relevant to real-world challenges, such as sustainable resource management. These insights, when effectively communicated, align with principles of accessibility, memorability, emotional appeal, and shareability, which are critical for engaging broader audiences through educational tools or social media platforms (Borchert et al., 2010; Baek et al., 2014).

Understanding complex system dynamics such as the impact of individual irrigation activities can only be made visible by bringing stakeholders together in a participatory setting that allows holistic discussions and explorations as demonstrated in different studies (Garrod et al., 2013; Nikkels et al., 2019a; Nikkels et al., 2019b; Mussehl et al., 2023). Studies have also reported that pre–post-game analyses help highlight the changes from the baseline positions (conventional perspectives) such as improved understanding, learning, collaboration, etc. (Peña et al., 2018; McConville et al., 2023). The results in this study reveal that the "pro-harvesting opinion type" only appeared after the ENGAGE game sessions, while most of the other opinion types were labeled with the "blamers" label. However, this opinion type disappeared after several months. This may indicate that this type of opinion emerged due to game experiences which influenced game participants' conventional perceptions. There is a higher chance that the experiences during gameplay where participants were subjected to increasing demand for water to support livelihood activities, household needs, etc., versus the reducing downstream flows, and emerging downstream–upstream tension and conflicts, provoked the need for water harvesting opinion type after playing the game. These observations were further reported in the post-game interviews and debriefs. For instance, the key cross-cutting lessons included: (i) importance of water storage, (ii) the value of stakeholder engagements, (ii) effective water resources management, and (iv) fair sharing of water resources. This indicates that the ENGAGE game triggered a deep reflection of human–water issues among the participants.

Comparing pre-game and post-game sessions, the results indicate that the ENGAGE game seemed to have built a consensus on the awareness of the link between catchment location and water scarcity in the study catchment, the impact of market opportunities (e.g., export companies), on water resources availability, and recognition of illegal river water abstractions as a major contributor to water shortages. Interestingly, despite building consensus, an increase in disagreement after playing the game was also observed in other

1. The water storage is the most important activity to solve water scarcity problems
2. The solution is to engage all stakeholders along the upstream–downstream gradient
3. The game informs on effective water resources management
4. The game demonstrates how fair sharing of water resources can be achieved
5. There is a need to change high-water-demanding farming practices
6. There is a need for efficient irrigation methods
7. There is a need for collectiveness/community approaches
8. The game reminds us that the solution is not in fighting or blaming one another
9. There is a need for upstream people to consider downstream people
10. There are feasible solutions to reverse downstream water scarcity

FIGURE 4
Key lessons of ENGAGE game sessions. Summarized based on the post-game video interviews.

aspects such as uncertainty about climate change as a major effect on water resources availability and whether pastoralist communities increase their livestock numbers in order to boost their wealth, hence the greatest suffering in the downstream zone during dry seasons. This increase in disagreement indicates that different game participants shifted their perspectives hence an increase in the Z score variance.

Since there, was no playing the game during the post-post-sessions, it appears that stakeholders returned to the "blamers" type of opinions a view observed before playing the games. The increase in disagreement could also be attributed to other factors beyond ENGAGE game influence, such as demographics, geographical location, and gender of participants. For instance, analyzing the characteristics of participants in the different opinion types (Table A3), it appears that the "older" and the "wealthier" participants were observed to load into the "urban blamers" opinion type. The pro-rainwater harvesting opinion type was male-dominated and was characterized by younger participants from the upper slopes. Although this study did not primarily focus on this aspect and was limited to a sample size of five game sessions, preliminary observations suggest variations in perspectives influenced by factors such as individual capacity, age, gender, and geographical location. This is especially relevant given that most researchers do not conduct post-post-game Q-sort sessions, which can assess the stability of changing human–water perspectives. We opine that game participants demographics need to be accounted for and their implications further investigated in serious gaming research studies.

Given that profit-making is one of the primary priorities of many stakeholders in the study catchment (Wamucii et al., 2023), a disagreement with catchment economic statements seems to have deepened after playing the ENGAGE game. However, after several months (i.e., post-post-game), the participants perspectives changed, and an agreement was observed on market opportunities in the catchment (e.g., export companies) encouraging more farmers to increase crop production, which increases river water abstractions. This shows the importance of post-post-game follow-ups to confirm whether the stakeholders' perspectives and changes observed during gaming sessions are sustained beyond the game environment (Iacovides and Cox, 2015; Poels et al., 2015). For instance, after playing the game, most participants agreed that water governance and management issues are a concern, especially with uncontrolled illegal water abstractions as major contributors to water shortages in the catchment. However, after several months, participants did not seem to have a strong opinion on the inability of river basin organizations to effectively govern and manage water resources in the catchment.

The Q-sort results also helped to reveal unexpected perspectives. For instance, rainwater harvesting has been reported as not a widespread practice in the study catchment (ADF, 2005; Wamucii et al., 2023). However, in the pre-game sessions, it was ranked as an important activity in three out of four opinion types. This could indicate stakeholders are aware of the importance of rainwater harvesting, the lack of practice could be as a result of other factors, e.g., financial incapability but not a lack of awareness as had previously been assumed. These types of observations can be overly critical when drawing up catchment management plans, especially with a clear understanding of the "stakeholders" opinions.

This study reveals the Q-method's importance in differentiating issues that are volatile (i.e., those likely to change due to game sessions) and those that are stable (i.e., where stakeholders have a common perception, where no major changes were observed after game sessions). For instance, the lack of prominence of land-use issues and population issues in the Q-sort results does not mean they are less important for the game participants. The fact that land-use and human population issues appeared to have lower values of Z scores and variance indicate a common perception among game participants. In other words, the probability of these two issues plotting high in a normal distribution curve (e.g., from a household survey) is very high. This concurs with the research stating that land-use changes and human population dynamics are major drivers of the changes observed in catchment water resource variations (Dwarakish and Ganasri, 2015; Berihun et al., 2019; Sridhar et al., 2019; Swain et al., 2021; Lei et al., 2022). This suggests that the Q-method can be used to highlight the stakeholders' perspectives on various human–water issues. Additionally, this type of revelation can be instrumental in refining serious games such as modifying the ENGAGE board to different versions based on the encountered area of interest or aim. The Q-method approach has been applied to modify serious games or validation as reported by Kornevs et al. (2019) and Van Gaalen et al. (2022).

Importantly however, this study shows that the potential impact of the ENGAGE game on stakeholders' perspectives beyond the game environment can be illustrated with maintained consensus on three issues; (1) recognizing that the location of the catchment is on the drier side of the water tower, hence a water-scarce environment, (2) the increasing market opportunities in the catchment encourage more river water abstractions, and (3) illegal river water abstractions are major contributors to water shortages in the catchment. These three issues had a higher disagreement in the pre-game sessions, but this was reduced immediately after playing the ENGAGE game and these changes were maintained and observed several months later.

4.1 Study limitations

Despite the promising results of serious gaming influencing changes in stakeholders' perspectives in the pre-game, post-game, and post-post-game, there could be limitations that may have skewed the results of this study. Firstly, the Q-method heavily relies on the data provided by the participants, and there is no straightforward way to prove that the participants' Q-sort data is a true representation of reality. For instance, the game workshop environment, where the participants were meeting for the first time, may have influenced them to provide a "skewed" representation of their perspectives. Perhaps conducting pre-interviews at the individual/farm level, where stakeholders can be assumed to be comfortable could be a better option. A door-to-door approach is regarded as a valuable approach as participants are more relaxed, feel safe, and neutral (Hillier et al., 2014). However, conducting Q-sort at the individual level may be more time-consuming and costly.

The Q-sort sessions in this study were tied to participation in the ENGAGE game. It should be noted that one major limitation of serious gaming is the number of persons who can be engaged in a single game session. Given the research focus of this study, there were limitations on the number of participants who could participate in the Q-sort sessions, for instance, it was not possible to replace the eight participants who were untraceable during the post-post-game Q-sort sessions. The observation of the increase in the number of Q-statements showing consensus and diversity in opinion in the post-post-game sessions indicates a need to have considered a larger sample size. This would have allowed more comparative analyses by subjecting some game participants to a "post-post" gameplay and others with no gameplay. This would have given more insight into the effect of gaming especially on volatile issues and also as a "check" on the stability of the identified common perceptions and opinions. In addition, in the Q-sort analysis, the setting of significance level, e.g., at $p < 0.05$ to flag participants or setting significance at $p < 0.01$ for identifying the most distinguishing statements may have affected the results of the study. Different significance level settings may have influenced the number of factors extracted, the number of participants flagging different opinions, etc.

5 Conclusion

The comparison of pre-game, post-game, and post-post-game sessions reveals significant shifts in stakeholders' human–water perspectives following participation in the ENGAGE game. Participants demonstrated a greater recognition of key catchment issues, including the water-scarce nature of the region, the impact of increased market opportunities on river water abstractions, and the role of illegal abstractions in water shortages. The game reduced disagreements on these issues, with perspectives persisting months later. The study highlights the value of the gaming approach in enhancing understanding of stakeholder interactions with hydrological systems, influencing human–water perspectives, and identifying areas of consensus and diversity over time. Practical game experiences, such as visualizing declining water resources and livestock migration during dry seasons, appeared to influence participant perspectives, suggesting the efficacy of experiential learning through serious gaming. The study underscores the potential of Q-methodology to identify volatile and common perceptions, providing insights for policymaking and catchment management. While the results are promising for socio-hydrological scientists, water managers, and organizations, further research is needed to explore the games' effects on individual behavioral changes. This includes conducting more post-game follow-ups, Q-sorts, and on-farm surveys, as well as examining how factors like wealth, profession, gender, and location shape stakeholder perspectives in serious gaming contexts.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

CW: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing – original draft, Writing – review & editing. PO: Methodology, Supervision, Writing – review & editing. AT: Supervision, Writing – review & editing. AL: Supervision, Writing – review & editing. JG: Supervision, Writing – review & editing. ES: Formal analysis, Funding acquisition, Methodology, Resources, Supervision, Validation, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frwa.2025.1539080/full#supplementary-material

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