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Assessing the potential to use serious gaming in planning processes for sanitation designed for resource recovery

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ABSTRACT

There is an urgent need for innovations in the sanitation sector to minimize environmental impacts and maximize resource recovery. Uptake of innovations may require changes in established technical practices, organisational norms and/or individual behaviours. Achieving change in any of these areas requires influencing *cognitive*, *normative* and *relational learning* processes. Serious games have been identified a potential tool for planners and environmental managers to influence such learning processes. This study designed the serious game RECLAIM to share knowledge about resource recovery from sanitation and to support attitude-change and collaboration between players. A structured framework was applied to assess if the game: 1) increased understanding of resource recovery (*cognitive learning*), 2) changed worldviews (*normative learning*), 3) led to more collaboration (*relational learning*), and 4) was a positive experience. Proof-of-concept testing of the game in Uganda found that it was positively received. The game provided cognitive learning on environmental and health impacts, resource recovery, and sanitation in general. Players gained an appreciation of the need for collaboration and it was deemed to have the potential to influence worldviews of a larger stakeholder group. Future recommendations include embedding the game in planning processes, including several gaming sessions that would strengthen cognition learning and the potential for changing practices.

1. Introduction

The water and sanitation sector has made significant progress in supplying water and toilets to people around the world (WHO/UNICEF, 2021). Indeed, the flush toilet has been heralded as one of the most important inventions of the industrial age and it revolutionized urban sanitation (Ferriman, 2007). However, this golden standard has significant drawbacks, including excessive water use (Larsen et al., 2016), nutrient mismanagement (Fuhrmeister et al., 2015) and high costs (McConville et al., 2019). On a global scale, the waterborne sewerage system is an unsustainable solution for future sanitation (Guest et al., 2009; Larsen et al., 2009). Even if everyone was connected to a waterborne toilet and treatment plant, 32% of the nutrients in the wastewater would still be released to the environment (Fuhrmeister et al., 2015). Resulting in eutrophication and disruption of the biogeochemical flows of nitrogen and phosphorus that are recognized as critical planetary life-support systems (Steffen et al., 2015). As the infrastructure for capture of human excreta improves (SDG 6.2), it becomes increasingly clear that the next big challenge is to treat captured wastewater responsibly (SDG 6.3) and to increase resource recovery (SDG 12.5). While we find solutions to safely treating the excreta from 4.5 billion people that are currently discharging untreated wastewater (WHO/UNICEF, 2021), we must also move towards more circular management of water and excreta resources (Water Europe. 2020).

There is therefore an urgent need for innovations in the sanitation sector that lead to minimizing environmental impact and maximizing resource recovery. The good news is that a growing number of technology solutions for nutrition recycling are available, in the form of both new toilets and new treatment technology (Harder et al., 2019). However, few are widely used today. This is because implementation of these solutions requires major transitions in a sector characterized by high levels of path dependency in infrastructure development (e.g. technical lock-in), strong social norms and inflexible management organizations (McConville et al., 2017). Improving our capacity to recycle valuable

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resources from wastewater demands a transformation in service standards, organizational roles and responsibilities (Lennartsson et al., 2019), and overcoming institutional and cultural barriers that favour traditional centralized sewage systems (Fuenfschilling and Truffer, 2014). Indeed, studies in sustainable transitions suggest that affecting change needs to take place at multiple levels (Geels, 2002). For example, introducing innovations requires changes in the mainstream way of doing thing, i.e. the regime. The regime is shaped by *cognitive*, *normative* and *relational learning* processes that lead to established technical practices, norms and social rules (Geels, 2004). Thus, introduction of sanitation innovations needs to be able to influence these processes.

There is evidence that the established technical practices, norms and organisational structures in the sanitation sector need to change if we are to increase resource recovery and sanitation for all. Indeed, a study of the sanitation sector in Uganda found that knowledge taught in universities is dominated by information on centralized sewage systems, despite the fact that these systems serve less than 1% of the population (McConville et al., 2022). The same study found resource recovery to be low on the list of prioritized sectors values and a need for better coordination between actors in the sanitation service chain. The same situation has been identified by experts at the World Bank who point at the need to think differently in order to achieve city-wide inclusive sanitation (CWIS), including shifting engineering curricula and consulting firms to include more non-conventional systems and innovation, as well as the need for wider cooperation in sanitation service planning (Gambrill et al., 2020). An emerging paradigm shift towards CWIS is growing based on principles that include services for everybody, a diversity of technical solutions with considerations for reuse and well-aligned institutional arrangements. However, the principles behind this shift have yet to be integrated into planning frameworks (Narayan et al., 2021).

Planning processes based on collaboration and shared learning, where multiple stakeholders create shared visions and experiment with new ideas, is one way to influence engrained socio-technical structures (Kemp et al., 2007). Creating this type of planning process requires new tools, especially communication and learning tools that take into account and bring together different stakeholders' perspectives through dialogue and social learning. An increasingly popular tool for supporting learning and collaborations in urban and environmental planning is serious games. Games have been shown to be effective in understanding complex systems (Raghothama and Meijer, 2018), have a significant positive impact on social learning (Wendel and Konert, 2016), increase participants' engagement and enjoyment (Reinart and Poplin, 2014), and promote trust and shared reflection (Gordon and Baldwin-Philippi, 2014; Poplin, 2014). According to den Haan and van der Voort (2018), learning outcomes from serious gaming can impact on three categories of learning: 1) cognitive learning through increased understanding and awareness; 2) normative learning through changes in views or values; and 3) relational learning through improved understanding of others' perspectives and enhanced ability to cooperate. In addition to learning, serious games should evoke a positive experience and motivate players to take action through a "gameful" experience (Högberg et al., 2019).

A number of serious games exist for water management and planning (Aubert et al., 2018) and the concept is increasingly used in the sanitation sector. For example, RELIEF CAMP MANAGER helps players to plan for sanitation provision in an emergency setting (Aslam et al., 2017). There are also games for nutrient management, such as NITROGENIUS that models nitrogen flows (Erisman et al., 2002). Yet, the authors are not aware of sanitation games specifically designed to promote a transition to nutrient recovery from sanitation. The degree of assessment of these games varies widely and few studies rigorously evaluate whether serious games can fulfil the goals that they set out to achieve (Aubert et al., 2019). According to the typology of serious games used by Rodela et al. (2019), expected outcomes should relate to the purpose of the game, e.g. educational games designed for teaching/training can expect gained skills and knowledge as an outcome.

In light of the desired transition in the sanitation sector and based on the potential of serious games to support necessary learning, we designed a serious game to share knowledge about resource recovery from sanitation and to support attitude-change and collaboration between players. This study is designed as a proof-of-concept as to whether the game can achieve these goals. Specifically, we focus on the degree to which players reached: 1) an increased understanding of resource recovery (cognitive learning), 2) a change in worldviews (normative learning), 3) an improved understanding of others' perspectives and need for collaboration (relational learning), and 4) a positive gaming experience.

2. Theory

The overarching aim of the serious game developed in this study is to be a tool within the on-going paradigm shift towards inclusive and circular sanitation systems. Thus, we need to understand how a game can contribute to learning and socio-technical transitions. This section provides the theory behind the game, as well as how this theory was integrated into the game design.

2.1. Serious games, learning and transitions

Sanitation systems must be understood as socio-technical systems in which social structures, norms and organization, interaction with technical objects. There is a growing body of knowledge that aims to understand how transformations in socio-technical systems occur (Köhler et al., 2019). There is general agreement that transitions occur when technical innovations interact and modify existing norms and social rules (Geels, 2011). This requires changes in peoples' cognitive understanding, including the knowledge and shared experiences that define their mental models of reality and influence how actors solve problems (Geels, 2006). Studies on technological innovations show that knowledge development and dissemination are critical functions in the emergence of new innovation (Hekkert et al. 2007). Shared values and norms within society will also determine the social appropriateness of solutions (Geels, 2004). Establishing the legitimacy of new concepts like circular sanitation systems is thus also critical, as it is closely connected to supportive policy and market development (Bergek et al. 2008). In addition to the cognitive and normative rules that dictate actions, the relationships between actors and organizations, i.e. social capital, will shape the possibilities for new technologies/actors to emerge (Geels, 2004). Thus, transition studies highlight cognitive, normative and relational changes as necessary to support transitions.

A key factor enabling socio-technical transitions is social learning (Bos and Brown, 2012). Social learning is a change in understanding that goes beyond the individual to diffuse to members of a wider social unit through social interaction within a social network (Reed et al., 2010). Social learning can thus contribute to changing an individual's cognitive understand and norms, but also influence actors that govern decision-making processes (Pahl-Wostl, 2009). We envision this happening through a collaborative experience in which individuals experience new normative perspectives in a group setting.

Serious games may be one tool to help facilitate sustainable transitions since they can be linked to cognitive, normative and relational learning at the heart of socio-technical transitions (Fig. 1). Kemp et al. (2007) have suggested that transitions can be enabled by targeting planning processes to make them more collaborative, based on shared sustainability visions and an openness to new ideas. Serious games are increasingly used in many sectors as a creative way to engage people and increase learning on complex sustainability (Hallinger et al. 2020). A review of serious games used to enhance social learning on sustainable management of land and natural resources, found that the games targeted cognitive, normative, and relational learning outcomes (den Haan and van der Voort, 2018). Serious games most commonly target cognitive learning, specifically raising awareness and increasing

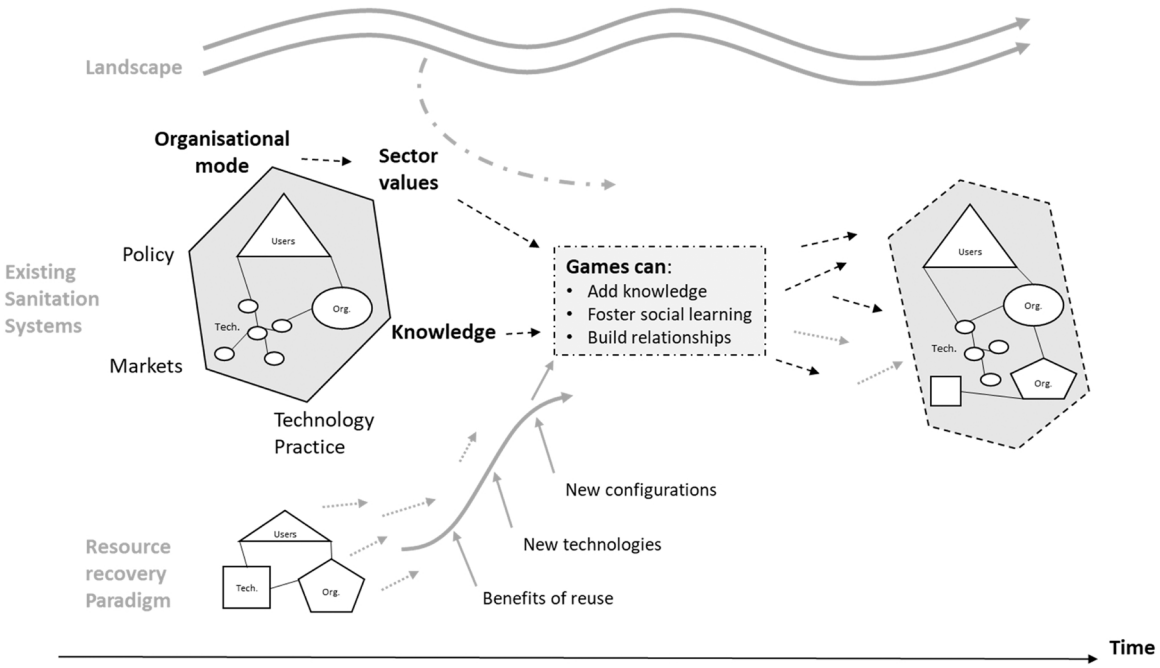

Fig. 1. Socio-technical transitions emerge from the interactions between the existing system (regime), new ideas (niche) and macro-landscape factors. The regime is dictated by dominant organisational modes, values, knowledge, technology, markets and policy. Based on theory, serious games can influence organisational modes, values and knowledge, e.g. relational, normative and cognitive practices.
(Figure adapted from (Fischer et al., 2021) & (Geels, 2002)).

understanding (den Haan and van der Voort, 2018). However, care must be taken in the game design process to assure rigor in the knowledge displayed in the game and connections to the real world (Raghothama and Meijer, 2018). While assessing normative changes from games is difficult, there is some evidence that serious games can changes participants attitudes (den Haan and van der Voort, 2018). In a game designed to explore the dynamics of climate change, evaluations found that players became more worried about climate change and felt it was more important to them personally after playing the game (Sterman et al., 2015). Another study could also link their role-playing game on natural resource management to changes in participants attitudes towards negotiation, yet eight months later their memories of the game were rather vague (Ducrot et al., 2010). Finally, serious games have been shown to facilitate and support collaborative or social learning (Wendel and Konert, 2016), e.g. by improving the understanding of different stakeholder perspectives (Barreteau, 2003) and building trust and joint reflection through playful interaction (Gordon and Baldwin-Philippi, 2014). However, building these relationships was reported more often when games were used in communities or existing projects where participants already worked together on shared issues (den Haan and van der Voort, 2018).

As illustrated in the text above, serious games need to be carefully designed to assure the intended impacts. In addition, serious games need to be embedded within a larger process, as the game alone will not create a transition. The following section explains how we designed a serious game for sanitation that can influence cognitive, normative and relational learning. The resulting game has then been tested to see if the concept works. However, the game would likely need to be embedded with a supportive planning process if it is to achieve transitional impacts.

2.2. Design specifications and intended outcomes for a sanitation game

To guide the design of a serious game to support the transition to resource recovery in the sanitation sector, specifications were developed (Kain et al., 2021). The general framework for the specifications was derived from a literature review of previous taxonomies and frameworks for urban and environmental planning games, in particular the taxonomy by Prieto De Lope and Medina-Medina (2017). The resulting framework covers six categories, including game design, game use, game users, game development, game platform and business model (Kain et al., 2021). The specifications in each of these categories defined a game that should support a transition in the sanitation sector towards the provision of sanitation services for all (SDG 6), protection of human health (SDG 3) and water resources (SDG 14), and the recovery of resources (SDG 12), specifically aided by source separation of waste flows (Larsen et al., 2009). It should be a strategy and role-playing game designed for use in sanitation planning, covering the entire sanitation service chain that is playable by a wide set of stakeholders in both Global South and Global North contexts. The specifications define a game that should share knowledge about resource recovery from sanitation (cognitive), support a positive attitude towards resource recovery (normative) and collaboration between players (relational).

The design specifications for *application area* and *content* (game design) define the intended cognitive learning from the game. Content of the game should include the sanitation service chain from collection and transportation to treatment and reuse (Tilley et al., 2008). It should provide knowledge on multiple technologies for resource recovery. Furthermore, data regarding the functionality of the service chain, depending on proper performance and connections between each component, and associated environmental/ health costs need to be included (Schütze et al., 2019). In particular, performance and consequences of different sanitation management practices and system solutions should be simulated to illustrate the implications of choices made in the game.

The design specifications for *world view* (game design) particularly define the intended normative learning from the game. The game is designed to highlight the fact that there are significant resources in human waste that can be tapped for agricultural and energy purposes (Rose et al., 2015). It should visualize the possibility to create circular loops of resource use and that it is beneficial to do so.

The design specifications for *game use* particularly define the

intended relational learning from the game. Here, the game is designed to illustrate that successful resource recovery demands collaboration between individuals, households, service providers and others (McConville et al., 2017). Thus, the narrative of the game is designed to foster collaboration between the different stakeholders playing the game. It highlights the quest to overcome sanitation obstacles through collaboration among stakeholders to forge a new sanitation system. To build collaboration even outside of the game environment, the game should be both engaging and develop trust by allowing players to have fun and reflect together (Gordon and Baldwin-Philippi, 2014). Through gameplay, players will have a chance to try out different roles (Medema et al., 2016), leading to an understanding of both "positive interdependences" (we can only succeed as a group) and "individual accountability" (individual results affect both the group and the individual) (Johnson and Johnson, 1999).

3. Methods

This study is designed as a proof-of concept of the serious game RECLAIM that was designed to support planners and other stakeholders to explore new systems for sanitation management with a particular focus on resource recovery. The design of the game was based on a preliminary set of specifications (Section 2.2., Kain et al., 2021) that were actualized through a co-design process with stakeholders (Section 3.1., Billger at al, 2020). The game was subsequently tested by stakeholders to determine its viability.

3.1. Co-design

Design of the game involved stakeholders from relevant organizations in an iterative cycle of game design, game testing and game assessment. A co-design process was chosen in order to avoid the organizational blockages that often impede the implementation of new dialogue planning tools (Billger et al., 2017). Roux et al. (2017) have shown that co-design involving both policy and research stakeholders can address such obstacles.

Game development started by carrying out scoping studies in Sweden and Uganda in 2017–2018, including interviews with municipal planning and sanitation officers in Sweden and stakeholders on both national and municipal levels within the water, environment and agriculture sectors, as well as with NGOs working with sanitation. Topics covered included challenges in sanitation planning; the current state, potential and perceptions of nutrient recovery within the respective sanitation systems; and the potential of serious gaming in this context. The interest among stakeholders to take part was significantly higher in Uganda compared to Swedish stakeholders who, due to time constraints, preferred to be involved when a game prototype was ready.

It became clear in the scoping interviews that most of the stakeholders in Uganda, were interested but not familiar with serious games. In February 2018, we arranged a workshop with 30 stakeholders in Kampala, were we tested role-play and introduced game elements in the workshop design. In retrospect, this turned out to be the actual starting point of the game development. A professional game designer worked closely with the research team and interested stakeholders to develop a working prototype. The research team and the game designer team held frequent play tests to choose between and adjust game mechanisms. A series of playtests of different versions of the game was carried out, including workshops with stakeholders in Kampala and Sweden in 2019. Prominent for the co-design process of the game, was the series of meetings with the sanitation planning officers from Kampala city where they guided us on directions to take. At several points the games was play-tested with different stakeholder (Fig. 2). The playtests were observed, participants provided individually written feedback before the groups reflected together, and the discussions between players were documented (Billger et al., 2020).

3.2. Resulting game

The resulting sanitation planning game is a role-playing analogue board game (Fig. 3 & Game rules in Appendix A). The objective of the game is to manage waste created in the city, feed the inhabitants of the city, and avoid pollution and disease. The board consists of hexagons forming a playing area that can be reshaped to represent the local urban landscape. Four players play the roles of housing, waste treatment, farming and private contractors. Each role has specific infrastructure that they can build and each player has a hidden agenda. The players take turns placing game pieces representing different technologies for housing, treatment, farming and transportation on the board, resulting in an emergent sanitation system. Players compete by collecting points for infrastructure that they build, however the game is also cooperative in that players can collectively lose against the game if their actions result in famine, disease or excessive pollution.

The possibility for resource recovery is represented by a six-sided resource dice that illustrates the different forms that nutrients/waste can take, e.g. food, mixed and separated excreta, fertilizers, sludge and disease. Chance cards are drawn every ten minutes to add an element of excitement to the game and allow for contextualizing the game with realistic events. The final version of the game includes pictures of different sanitation technologies on the point cards for housing and treatment so that players are exposed to a variety of possible technologies. However, these technology cards were not available during the user tests presented in this study.

A digital add-on in Microsoft Excel allows a facilitator to record the building actions taken during the game and thus simulate the result of these actions. The add-on visualizes the degree to which players succeed in providing sanitation services for all urban residents and recover nutrients, e.g. whether they achieved local food security or if they relied on imports of food and fertilizers. The visuals from the add-on provide a useful starting point for post-game analysis and reflection.

3.3. Design of a game-testing framework

RECLAIM has been designed to share knowledge about resource recovery from sanitation and to support attitude-change and collaboration between players. It was also designed to be a tool for social learnings for transitions through creating space for positive social interaction. The

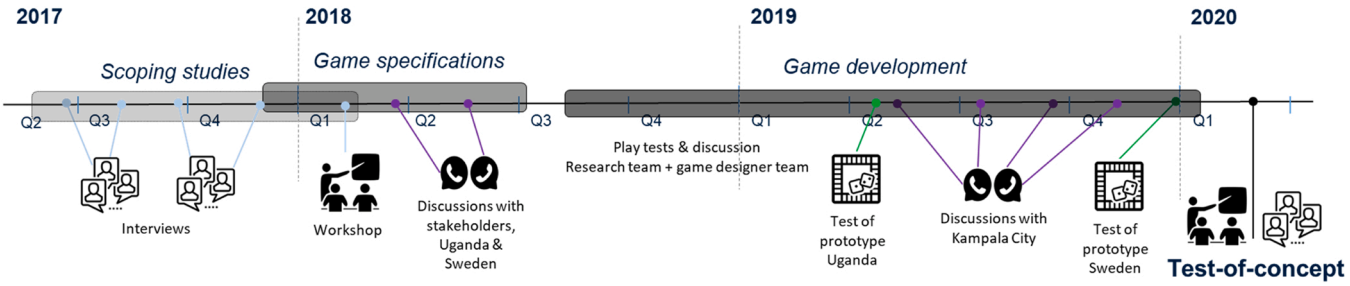

Fig. 2. Timeline of the co-design process for the RECLAIM game, from scoping studies, identification of specifications and game development.

Fig. 3. : The final RECLAIM prototype, including hexagon tiles for the board, resource dice, and infrastructure pieces and cards (photograph : Jaan-Henrik Kain).

Table 1
Overview of the structure used for testing the game. Data was gathered through pre- and post-game questionnaires and post-game interviews.

Expected outcome		Quantitative assessment		Qualitative assessment	
				Questionnaire	Post-game interview
Cognitive learning	Individuals playing the serious game **gain knowledge** about the different possible alternatives recovery resources from sanitation.			Did playing the game give you any new ideas for sanitation planning? *(Post-game only)*	Did you get any new ideas from the game?
				What aspects of sanitation services did you feel were highlighted in the game? *(Post-game only)*	The game aims to share knowledge about resource recovery from sanitation and supports attitude-change and collaboration between players. Do you feel that it achieves this goal?
Normative learning	Individuals playing the serious game form a **more positive attitude** towards resource-recovery.	*Pre-* vs. *post-game*	5 Likert-scale questions on impacts of sanitation[+] 2 Likert-scale questions on how the player prioritizes sanitation. 5 Likert-scale questions on perceptions of resource recovery, including sliding scale from waste to resource. 10 Likert-scale questions on risk perceptions and acceptance of resource recovery.		Do you think that the game influenced you with regards to … – how important you think sanitation is? – how you view the impacts of sanitation? – whether you view excreta as a waste or a resource? – whether treated excreta can replace imported fertilizers? – - how you see acceptance of eating food fertilized with excreta, including manure?
Relational learning	Individuals playing the serious game have an **increased understanding** of need for **collaboration** between players.	*Pre-* vs. *post-game*	Who needs to be involved in sanitation services? vs. Who do you think needs to be included in the next planning workshop for sanitation services?	Did playing the game give you any new ideas on how to develop sanitation planning? *(Post-game only)*	If you were to decide, what would you propose to do with sanitation services in the future? *Who needs to be involved? Why?*
	Individuals playing the serious game experience collaboration.	6 Likert-scale questions regarding group atmosphere* *(Post-game only)*		What aspects of sanitation services did you feel were highlighted in the game? *(Post-game only)*	
Experience	Individuals playing the serious game have a positive experience.	6 Likert-scale questions regarding enjoyment and group atmosphere* *(Post-game only)*			What did you think about the gaming activities?

[+] Post-game questionnaire were worded with opposite meaning.
* Adapted from Aubert et al. (2022)

testing of the RECLAIM game was thus two-fold: first to assess if the game fulfilled the intended outcomes for cognitive, normative and relational learning and second to document how the players experienced the game (Table 1). These learning categories reflect the aim of the game, as well as being representative of learning outcomes commonly expected from collaborative serious games for sustainability problems (den Hann & Van der Voort, 2018).

Sanitation planning is a truly open and multi-level system with many internal and external factors at play. Thus, it is difficult to isolate how individual factors, such as game play, would influence planning and learning processes. For the purpose of testing proof-of-concept in this environment, assessment based on stakeholders' judgement, e.g. their qualitative appraisal, was selected as the main approach to understand the context-specific relevance of RECLAIM (Joseph-Richard and McCray, 2022). A mixed-method approach was applied to capture outcomes from game-play by engaging with both quantitative and qualitative data, where quantitative data provided overview and qualitative data analytical depth, seeking out stakeholders' "relative and tentative judgment" (Picciotto, 2022) based on their expertise. This was done both to obtain different levels of information, but also as a way to triangulate answers.

Assessment of learning in the three target areas was done using self-reporting methodologies in questionnaires and open-ended interviews. Self-reporting is a valid method for assessment of mental processes, including cognitive processes and learning (Pekruna, 2020). However, some researchers question the reliability of self-reported answers, especially in terms of memory bias that change over time or that respondents will anticipate the social desirability of answers, biasing the responses. Thus, it is recommended that self-reported data be complemented by other performance data (Gonyea, 2005). For the proof-of-concept testing of RECLAIM, we triangulated responses to multiple self-reported questions (both written and oral). However, full evaluation of learning outcomes would require other methods such as performance and behavioral change data, as well as a long-term follow-up.

Pre- and post-game questionnaires were designed to be taken by the players immediately before and after game play (Appendices B and C). Using pre- and post-questionnaires allowed for identification of learning aspects that were stimulated or attitudes that changed by the use of the game. The questionnaire included both Likert-scale questions and open-ended questions with free-text responses. Open-ended questions were purposely vague to avoid biasing answers, e.g. what do you feel was highlighted in the game. In addition, each player participated in a semi-structured interview after playing the game (Appendix D). Interview questions were designed to probe deeper into concepts that players felt were stimulated by the game (Table 1). Most interviews were conducted within 1–3 days after playing the game, however three took place immediately following the game play while one took place a week after the game was played. Thus, the game was still a fresh memory for participants.

The resulting assessment framework is designed to show if the players feel that they experience learning and if they judge the game to be relevant to their context. Such a stakeholder-based approach to assessment assures that the findings are sound in relation to the complexity of the particular sanitation context of the game-testing, and are likely to be relevant for similar sanitation contexts. However, the validity in other contexts need to be analysed further through additional studies.

3.4. Testing proof-of-concept

The game was tested using gaming workshops in Kampala with interested stakeholders in February of 2020. Eighteen players participated in these workshops, including representatives from local universities, Kampala Capital City Authorities (KCCA), the municipality of Nansana within the Greater Metropolitan Region of Kampala, the National Water and Sewerage Corporation (NWSC), and the Ministry of Water and Environment. Some of the players had participated in the co-design process of the game while others were new to the concept of serious gaming. The majority of the players (11/18) were between 30 and 39 year of age, with five players between 40 and 49 years of age and 2 players in their 20 s. The players were gender balanced with 10 male participants and 8 women. Most players (8/10) had 5–10 years of experience working with sanitation, and five players reported more than ten years of experience. Five players reported less than five years of experience and only one player reported no experience working with sanitation.

Three gaming workshops were held, two smaller workshops with only one game being played (with five and three players respectively) and one workshop with two game tables played in parallel (five players at each table). Each workshop started by welcoming the participants and asking them to fill in a consent form and the pre-game questionnaire (~30 min). Following this a presentation was given to introduce the game, including an introduction to the research project, reasons for playing serious games, the aim of the game and how to play. Each game table was assigned a facilitator who could answer questions and fill in data on the digital add-on (the Excel model). Game play in each workshop took between 90 and 120 min. During the first round, the facilitator assisted players in understanding the rules and even suggesting moves to keep the flow of the game going. However, during later rounds the facilitators limited their interaction to specific questions and assisted only when players got stuck. Following the game, the players participated in a discussion about the results of the game, including the simulated results from the digital add-on, and their experience while playing. Players were provided with questions to guide their discussion (semi-structured questions, Appendix 3) and the facilitators prompted players when necessary to keep the discussion going. After the discussion, players were asked to fill in the post-game questionnaire and participate in a semi-structured interview.

The results from the questionnaires were analysed both quantitatively and qualitatively, depending on the question (Table 1). Quantitative analysis compared the results of the Likert-scale questions regarding attitude in the pre- and post-game questionnaires. It also quantified the difference in the number of stakeholders named in response to the questions related who needs to be involved in sanitation. The post-game Likert-scale questions on their experience of the game were also quantitatively assessed. Due to the small number of participants no statistical analysis was done. Rather, the quantitative results provide an overview of trends within learning and players' experiences. Qualitative data was analysed to obtain a more in-depth picture of stakeholder judgement of the learning and experience connected to the game. Open-ended questions in the questionnaires were qualitatively analysed through coding in the software NVivo©. Qualitative analysis of the interview material (both audio recordings and transcribed notes) was done by coding of each interviewee's answer to identify emerging key concepts and trends.

4. Results and discussion

The results are presented and discussed according to the expected outcomes.

4.1. Cognitive learning

To start with, it is worth noting the participant's cognitive background prior to playing the game. The majority of participants had the pre-conception that sanitation services are primarily needed to protect public health (14/16 responses). In addition, several players linked the need for sanitation to environmental protection (6/16) and to securing social development and livelihoods (6/16). Reuse was only mentioned by one participant in connection with sanitation in the open-ended questions in the pre-game survey. However, a majority (15/16) of

participants already believed before the game that human excreta contains resources that we should recover.

At the cognitive level, players were expected to gain knowledge about resource recovery from sanitation. All players responded in the post-game questionnaire that they gained new insights from playing the game. In the open-ended question regarding new insights, the most common responses where related to new ideas regarding planning (7/18), collaboration (5/18), and reuse (3/18). Specifically, ideas relating to planning included the need to plan for the entire sanitation service chain, have all stakeholders on board and balance service provision with disease threats and food accessibility. Relating to reuse, players named insights in reuse logistics, benefits of a holistic approach and the need for sensitization regarding how treated waste can be beneficial to society. In addition, players mentioned learning related to minimizing risks for disease and upgrading old treatment units.

In response to the survey question on what was highlighted in the game, responses pointed towards reuse, recycling and nutrient recovery (12/17), treatment of waste (9/17), and the sanitation service chain (4/17). Additional items that players felt were highlighted included transportation, costs and financial commitments, the potential for non-sewered sanitation, and proper planning.

In the interviews, players named a broad range of ideas that arose from the game. The most prominent comments were about the need for new planning processes, the inclusion of more stakeholders and the development of resource recovery. Players discussed the need for improved technologies, in order to get the most out of the waste and convert it to fertilizer that can produce the food we consume in cities. While players recognized technical concepts in the game, they also saw that the game highlighted interconnections between social and technical parts of the sanitation system. The discussion of sanitation solutions that arose in the interviews showed a highly competent group of players with many ideas for improving sanitations services. They identified the lack of budget resources as a problem and that there is a great need to ensure enough money for infrastructure. The players proposed different ways of reorganizing sanitation planning and services on different levels, including ways to involve the private sector to develop new business models. They also proposed strengthened policies, improved regulations, and the use of enforcement. The players recognized a strong will in Uganda to expand the sewage coverage, especially in towns. However, they also acknowledged that sewage cannot be an option in all places and that other kinds of services need support, e.g. by upgrading on-site sanitation (improved latrines), reducing shared sanitation and increasing of the number of latrine emptiers. .

> *"I think that the game is like a puzzle that can lead to concrete solutions. You can go a shortcut, but at the end it will catch up with you. "*

RECLAIM aimed to share knowledge about different possible alternatives for recovering resources from sanitation. At a conceptual level, it seems clear that the game highlighted the potential for reuse and provided players with insights into how to build circular systems. While RECLAIM players may not have learned the specifics of alterative technical options, they did seem to grasp the complex interactions needed to establish circular resource systems. This result is in line with evaluations of other serious games that were found to support understanding of complex systems (Mochizuki et al., 2021) or environmental policy issues (Rebolledo-Mendez et al., 2009).

Furthermore, in their study of the use of a simulation game in adaptive planning processes, Lawrence and Haasnoot (2017) found that cognitive learning in the game created space for changing practices by supporting players to acquire new knowledge and/or restructure existing knowledge. They documented that the use of a simulation game gave players new ideas that allowed them to question their previous practice. While the present study has not used the game within an embedded planning process, players of RECLAIM did report a similar reframing of the sanitation problem, something that may open space for innovative practice.

Finally, cognitive learning is most effective when activities are repeated over several sessions (Lumsden et al., 2016). Unfortunately, this study could not follow-up repeated use of the game due to the pandemic. However, in post-game interviews players expressed interest in playing again. Future recommendations would be to embed the game within a planning process, including several gaming sessions that would strengthen cognitive learning and the potential for changing practices. This could also include an incremental increase of system complexity and/or adding more details regarding technical, social, economic, institutional, etc. issues in subsequent game play.

Fig. 4. : Players' perceptions of excreta as a resource. Weighted average responses to Likert-scale questions in the pre-game questionnaire (dashed bar) and in the post-game questionnaire (solid bar).

4.2. Normative learning

The expected normative outcome of the game was that players would form a more positive attitude towards resource recovery. In general, players ended up being more positive towards recovering resources from human excreta after playing the game (Fig. 4). The increase is not large. Yet, keeping in mind that the majority of the players were positive towards resource recovery already prior to playing, it indicates that the game succeeded in presenting a positive view on resource recovery. In the interviews, players shared that the game emphasised resource recovery and for some of them the game had an influence on how they viewed the use of excreta as fertilizer (Appendix E). Overall, they strongly argued for excreta being a resource and they were all positive towards reuse during the post-game interviews.

Prior to game play, all participants were generally aware the untreated human excreta poses a health risk and that it can be treated to remove this risk (Figure E.5 in appendix). However, there were variations among the players in their own acceptance for reusing excreta as fertilizer for food, with some being willing and others less so. There is a slight positive trend in the questionnaire responses towards increased acceptance of buying fertilizer recovered from human excreta and consuming food produced with it. The exception to this trend being a slight reduction in willingness to consume food fertilized with sludge from a wastewater treatment plant. This is likely due to the highlighted risk of disease in the game (rolling the dice) when using sludge from conventional wastewater treatment plants. After playing the game, one player still thus expressed hesitancy towards using excreta for food production. In particular, players were not convinced that playing the game could make stakeholders (particularity people outside of sanitation planning) change their mind and lead to a broader acceptance of excreta as fertilizer. Two players argued that their friends would not accept such food, the main reason being poor treatment in Uganda today. Still, the general opinion seemed to be "*it is a resource if it is well treated and well managed*."

The majority of the participants were already strong proponents for sanitation, agreeing that it was a top priority even before playing the game (14/16). The game did not seem to affect players' understandings of the impacts of sanitation services on people's health, happiness and provision of local jobs, with all participants already before game play agreeing or strongly agreeing that sanitation affects these areas (Figure E.1 in appendix). Yet after playing the game, there was marginally more agreement towards prioritizing both sanitation and other issues (Figure E.2 in appendix). Also, the game appears to have raised awareness of other issues besides sanitation, as well as the interconnectedness of issues. In the interviews players gave examples of how certain aspects in the game where highlighted and affected their thinking, such as the linkage to the quality of homes and livelihoods, the need for proper management to hinder disease outbreak and the importance of transportation.

In the interviews, players described how the game influenced them and how they felt it could be used to influence others. In particular, players found that environmental and health impacts were well highlighted and visualized in the game. Several of the players mentioned the dumping of unmanaged waste into water bodies as an example of this.

> *"The pictorial.* e.g. *the [poop] dice in the lake. It is a picture that will be with me for a long time. Visualizing that on the board and seeing all of the blocks build up in the water. That was significant for me"*

RECLAIM aimed to influence players' attitudes towards resource-recovery. Assessing normative learning in the sense of changing viewpoints is difficult since this type of learning requires internal reflection and thus takes time to occur (den Haan and van der Voort, 2018). The results from this study show a marginal increase in positive attitudes towards resource recovery. This is in line with results from other serious games that were found to support normative learning and the convergence of perspectives (den Haan and Van der Voort, 2018; Flood et al., 2018). One could also assume that players with less initial interest in sanitation would have a stronger increase in positive attitudes. However, a review of social learning from serious games found that the mechanisms of games to affect such learning are poorly understood and risk being based on untested assumptions (de Kraker et al., 2021). Thus, the results from the present study should be interpreted with cautions since only a small group of users has tested the game and more long-term follow-up is needed to verify results.

Nevertheless, the present study shows that the use of serious games to changes normative views is possible by creating situations that allow players to experience and practice new thinking. Lawrence and Haasnoot (2017) found that the use of a simulation game for climate-change adaption allowed players to test new solutions and "experience" the results, which enabled changing mental models and practices. Behavioural psychologists have also shown how perspectives can be modified by reframing the experience of the user in simulations of real situations, allowing for new norms (Lennon et al., 2015). This brings forward the importance of realistic visualization so that players feel that game scenarios are realistic. Here, certain aspects of RECLAIM, such as the waste dice and digital add-on of fertilizer use, clearly made an impact on players thinking, while other aspects, such as the acceptance of food cultivated with recycled waste, were too abstract. One proposal from an interview was to add elements to the game that visualized this in a more realistic way so that "*vegetables will be the result*" – e.g. through a story or a short video. Such needs for additional visualizations or discussions beyond the gaming activity itself is in line with other studies of normative change. Examples of successful use of serious games for generating social learning and enabling social change have embedded game-based learning into ongoing processes of real-world stakeholder engagement (e.g. Lawrence and Haasnoot, 2017; Moojen et al., 2022).

4.3. Relational learning

The expected outcome from a relational learning perspective was that players would have an increased understanding of the need for collaboration between players – and by extension between diverse sanitation stakeholders. Similar to the normative assessment, we found that many players already understood this concept to some degree. Even before playing the game, the participants had a collaborative approach to sanitation. In the pre-game questionnaire, a majority (16/17 respondents) listed three or more stakeholders who needed to be involved in sanitation services. Quite a few responded "everyone" (6/17). Despite this, seven players included additional stakeholders in their post-game response, including agriculture (2 players), donors & finance (2), health & hygiene (2), waste management (2), housing (1), NGOs (1), private sector (1), reuse options (1), and transportation (1). Responses to open-ended survey questions also showed that players gained insights into the need for stakeholder collaboration (also see Section 4.1).

> *"All stakeholders should be consulted when planning for sanitation service delivery."*

In particular, players felt that the game highlighted the entire sanitation service chain from collection, transportation, handling, treatment to reuse/disposal.

> *"[…] it shows that we need to integrate the planning process to have all stakeholders on board"*

> "It highlighted the fact that, at a strategic level, all stakeholders are key, otherwise the sanitation systems once implemented will not function as planned"

In the interviews, players highlighted the ideas they gained regarding collaborative planning. The game was described as triggering "*outside the box-thinking*" for planning and for involvement of stakeholders and illustrating the need for serious strategic thinking. Participants described ideas on how to work as a team, including multiple

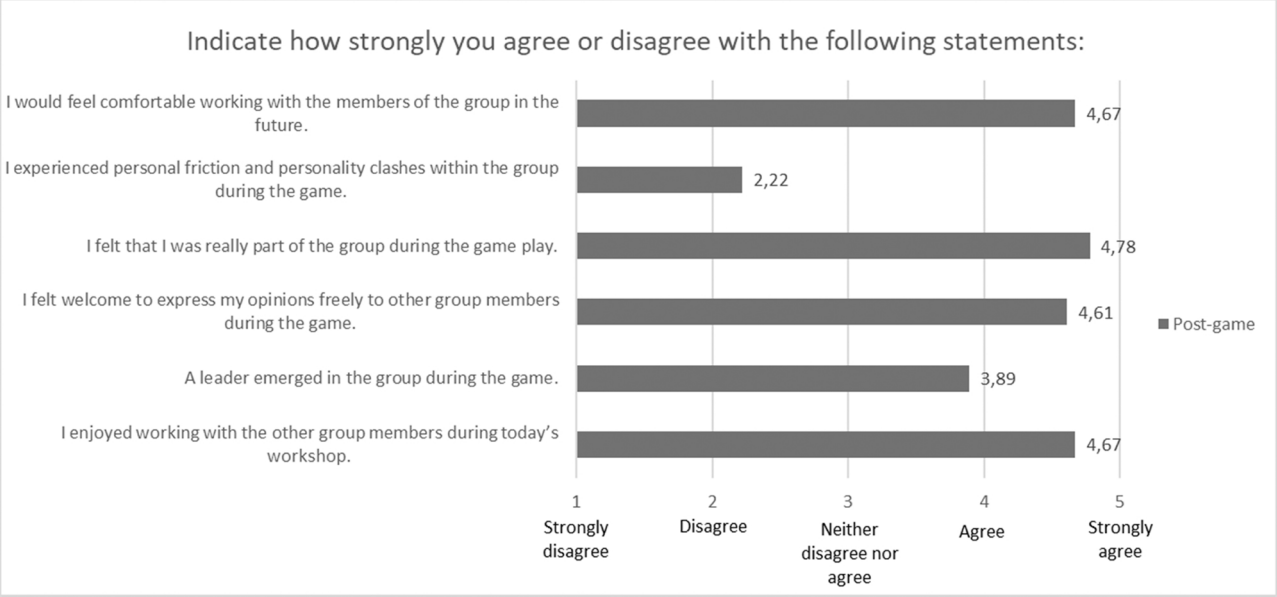

Fig. 5. : Players' perceptions of the game experience and group atmosphere. Weighted average responses to Likert-scale questions in the post-game questionnaire.

responsible institutions, and how to make collective efforts. They described the need for developing a holistic planning process that considers all stages and finding ways to prioritize properly. For example, one player pointed at the need to pool resources from different organisations/institutions into a common sanitation fund, thereby creating a base for prioritizing actions collaboratively. They noted that this implies recognition that others make decisions, and to recognise that different approaches can be included, for example that a technical view may be different from a city planning view. The need to get all stakeholders involved in the process was pointed out and the players stressed the need to include the private sector. The game also gave some of the players new ideas and a new tool for communicating and teaching the subject of sanitation. Even a player who found the game difficult to learn, claimed to finally have been influenced, because of the unexpected events that happened in the game (positive or negative) which were found to reflect the situation in real life. As one player stated, the game showed that *"sanitation is not a one-man game, it is everyone."*

The interviewed players thus emphasized the importance to involve everyone along the sanitation service chain. The need for ministries and governmental organisations, municipalities, and service providers to collaborate was underlined. Academic institutions were seen as important for developing technology and NGOs to be important in the implementation of better sanitations services, and for involving the community. The players also stressed that inhabitants (the users) need to be informed and educated. Suggestions were made for engaging religious and cultural leaders as a way to break through across cultural and political differences. It was pointed out that "*most of the planning ends up at the upper-end and the poor do not receive service*".

When it comes to collaboration experienced during game play, only one player disagreed that they enjoyed working with the other group members while the majority (14/16) strongly agreed to the same statement. All players agreed or strongly agreed that they felt being a part of the group, that they felt welcome to express their opinions during the game play, and that they would feel comfortable working with members of the group in the future (Fig. 5). This positive response indicates that players enjoyed the collaborative aspects of the game.

The RECLAIM game clearly succeeded in highlighting the need for collaborative planning in sanitation. Indeed, these results agree with previous findings that participatory games can provide players with a better understanding of alternative viewpoints and lead to greater cooperation. For example, a study of interactive games in planning contexts found that they prompted an openness to collaboration and recognition of the value of others' perspectives (Lennon et al., 2016). Indeed, Gurung et al. (2006) also found that use of a role-playing game allowed conflicting villages to better understand water problems and fostered collective communication. If designed right, serious games have the potential to support relational learning and stakeholder collaborations through including feedback loops, role-play, realism, low-risk environments and interactive elements (Medema et al., 2016). The game mechanisms in RECLAIM employ several of these elements, which lead players to gain understanding of the need for collaboration, as well as actually practice collaborative action in the game.

The challenge, however, is to translate relational learning in the game into lasting collaborative action in real-life. Other studies have shown that this is possible. The role-play game and accompanying multi-agent system model of water resources used in Bhutan by Gurung et al. (2006) helped transform a conflict situation into the establishment of an institution for collective watershed management. Similarly, a simulation-based board game designed to foster farming innovations supported collective learning and changes in interpersonal relations, thus leading to improved collaboration (Berthet et al., 2016). Meinzen-Dick et al. (2018) set out to measure the real-world impact of collaborative serious games and found that playing the game led to real-world impact, with a greater proportion of gaming-playing communities adopting rules and procedures for governing water resources compared to the control groups.

In all these cases, however, the serious game has not been a stand-alone activity, but has been embedded within a process of negotiation and/or planning. Indeed, embedding serious games within other processes may help to overcome a major limitation of serious games: time constraints. Limited time for working on stakeholder coordination (Medema et al., 2016) or participating in game activities (Meinzen-Dick et al., 2018) are critical barriers for use of these techniques. Time limitations were also discussed by players of RECLAIM as a potential barrier for use of the game with "*busy*" stakeholders, such as directors and politicians. Integrating the game within a planning process may legitimize game play. Alternatively, players also asked for a simplified version of the game to meet time restrictions.

4.4. Game experience

Assessment of the game experience focused on whether the players

had a positive experience. Overall, the game experience was positive for the players (Fig. 5). Positive exclamations were heard in the interviews about the game being fun, entertaining, engaging, stimulating, inspiring and beautiful. Players found the game to originate from reality and to be possible to adapt to the reality of the players. The game caught players' attention because it was interactive and kept people active, as well as giving them space reflection and decision-making.

> *"I think that gaming is the best approach for passing on practical knowledge. People can visualize the concept with ease"*.

The most appreciated features in the game were the different roles, dice, timer and event cards, collective decisions, hidden agendas, and the use of money. The choice of roles seems appropriate, and especially the private contractor was appreciated. Having a chance dice for revealing the outcome of some actions was also valued, creating a thrilling experience because of the risk-taking involved and the event cards drawn every 10 min were seen to bring both realism and excitement to the game. The players also felt that the collective decisions on how to use the city budget highlighted dilemmas of having to prioritize between the common good and personal interest.

Players considered the game to be well-designed and playable, but there was a diversity of opinions regarding how easy the game was to learn. Most of the players found the tutorial round (the guided first round) to be useful for learning, and that the game was quite easy to learn as they played. Still, they felt that it would be very hard to remember all the features if playing a second time. The real learning was found to be in round two and three when they played without guidance. Although much of the feedback was positive, there was criticism related to the levels of abstraction and the complexity of the rules. One player found the game hard to learn and felt that it showed its good sides too late in the game play. In contrast, other players felt that a learning period was both acceptable and necessary. Some of the players also wanted more realism by inclusion of other aspects such as solid waste, energy and fuel production, or linking financial aspects with the Kampala city budget. Still, such additions would add significant complexity affecting playability.

Overall, the outcome of playing RECLAIM found that players had a positive experience during the game, even if there were multiple suggestions for improvement. The game achieves the essential goal for any serious game in that it is engaging and motivational (Lumsden et al., 2016). In addition, serious games may create safe environment enables stakeholders with different perspectives develop trust by having fun and reflect together (Gordon and Baldwin-Philippi, 2014). By creating a safe environment, games enable social learning (Medema et al., 2016). Players of RECLAIM felt comfortable within the group and could freely express themselves – indicating that a safe environment was created, and that social learning was supported.

As referred to in the introduction, Högberg et al. (2019) stated that serious games should evoke a positive experience and motivate players to take action through a "gameful" experience. Meinzen-Dick et al. (2018) have shown that games can leave a "footprint" in the communities due to the memory of the positive experience of playing. In the RECLAIM game study, we found that the players had an overall joyful experience that evoked a strong drive to play. However, all emotions expressed during the play were not positive. Players showed frustration with the rules and disappointment when they needed to make uncomfortable decisions, e.g. polluting the water. Marsh and Costello (2012) point out that gameful experiences are not always positive but that serious games evoking a "serious experience" with negative emotions also support learning. A key to transforming mixed experiences into learning is the inclusion of a quality debriefing session after game play. Meinzen-Dick et al. (2018) found that repeated game play together with debriefing sessions made a significant impact.

While we can conclude that the game meets the requirements for creating a safe environment for social learning there is still the issue of implementing the game and bringing diverse players to the table. Two key aspects include deciding when to use the game in the planning process and who should play (Kain et al., 2021). The planning process should be carefully designed to support empowerment and inclusiveness, by adapting sessions for specific types of players at appropriate times and including relevant content. Based on this reasoning, we suggest a game toolbox, including modules and add-ons that would allow for flexibility in game length and content. In the RECLAIM study, the interviewees felt a need for players to be able to gain independence from the facilitator in order to be able to locate the game experience into an understanding related to their own practice. Facilitators of the game (e.g. sanitation planners) need to be trained to use a flexible game toolbox with different modules, including how to lead debriefing session in a way that can transfer game learning into physical planning processes.

5. Conclusions

The serious game RECLAIM was designed to support planners and other stakeholders to explore new systems for sanitation management with a particular focus on resource recovery. Assessment of gaming sessions found that the game increased the understanding of potential systems for resource recovery (*cognitive learning*). Players clearly gained an improved understanding of other perspectives and the need for collaboration in sanitation planning (*relational learning*). The game was also found to provide a positive and motivational experience (*game experience*), but it was difficult to measure whether players became more accepting of the concept of resource recovery (*normative learning*). Although players felt that RECLAIM has the potential to influence planners and other sanitation stakeholders, as well as politicians and decision-makers within their organisations, further studies are needed to investigate the full potential of sanitation games or gamified sanitation planning processes. While it is recognized that rigorous evaluation of game mechanisms is needed, it is also important to realize that the greatest potential of using games to facilitate transformative sanitation planning lies in embedding them within dedicated planning processes. Since learning is a process that requires repeated interaction and use of concepts, such an embedding would increase the retention of learning over time and utility of the results in real-world planning. Indeed, future work with the RECLAIM game is exploring how to create learning/planning modules from the game that can be integrated into different steps within a planning process.

We encourage further studies, to validate both the effects of gaming mechanisms and the use of RECLAIM or similar games embedded into real-life sanitation planning that could trigger and facilitate implementation of more resource recovery in sanitation systems.

CRediT authorship contribution statement

Jennifer R. McConville: Conceptualization, Methodology, Investigation, Formal analysis, Writing – original draft, Funding acquisition. **Monica Billger:** Conceptualization, Methodology, Investigation, Formal analysis, Writing – review & editing. **Charles B. Niwagaba:** Investigation, Writing – review & editing. **Jaan-Henrik Kain:** Conceptualization, Methodology, Writing – review & editing.

Declaration of Competing Interest

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

Data Availability

Data will be made available on request.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2023.04.002.

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