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Abstract. The aim of this study is to describe the development of an innovative planning tool to promote the knowledge and collaboration needed to overcome challenges in the sanitation sector. A serious game was designed to share knowledge about resource recovery and support attitude-change and collaboration between stakeholders. This study documents the co-design process of game development from conception based on a set of specifications the game should achieve, through iterative testing with relevant stakeholders as players. The resulting prototype of the game showed that it was not possible to include all the original desired specifications in the final game. Stakeholders found that the game was engaging, stimulated creativity and achieved its goal.

1. Introduction

Access to adequate sanitation is a basic human right that is recognized in the Sustainable Development Goal (SDG) 6 for Clean Water and Sanitation. SDG6 is closely intertwined with the goal for Sustainable Cities and Communities (SDG11) since access to sanitation (or lack of it) can critically impact on socio-economic development and environmental sustainability [1]. Alongside the momentum created by the SDGs, there is a new paradigm emerging which focuses on achieving sustainable sanitation through resource recovery and making services available to all [2]. However, the use of resource-recovering technologies is not yet widespread: uptake, implementation, and upscaling remain key challenges [3]. Achieving this paradigm shift will require knowledge development and cross-sectoral communication regarding possible sustainable service options for all; activities that can be supported through the development of tools for collaboration, knowledge sharing and planning [4].

Serious gaming has become an increasingly popular tool for learning and collaboration in urban and environmental planning. It has been found to be effective for understanding of complex systems [5], has significantly positive impact on social learning [6], increases engagement and enjoyment of the participants [7,8], and promotes trust and collective reflection [8]. Although there are a number of games in different types of water and flood basin management [9], serious games in the sanitation and wastewater sector are less prevalent. NITROGENIUS focuses on nitrogen flows [10], RELIEF CAMP MANAGER deals with provision of water and sanitation in disaster areas [11] and yet another game aims to engage social enterprises in sanitation provision [12]. Interestingly, playing some of these games has shown effects on the intentions of players [12] and on strengthening of collaborative learning around complex socio-ecological systems [13]. Still, there is a need for improvements of planning games in their abilities to encourage participation, interaction, learning and knowledge transfer [7]. Pros and cons of analogue and digital games are debated; analogue games may promote collaboration better than digital but are slower to play [14]. Additional, the level of abstraction of the game is an important aspect, i.e. if it provides a sufficiently realistic visualization of the context [7]. The challenge is however, to keep it simple enough to make it playable [15].

This paper provides insights and lessons learned regarding development of a serious game to promote knowledge and collaboration for resource recovery in sanitation systems. The main question for this research-driven initiative has been: How can a serious game that supports cross-sectoral

collaborative planning for sanitation systems that recover resources and provide services to all be designed? Specifically, this paper describes a sequence of game development and playtesting based on a co-design process, starting from a number of defined game specifications and transforming these into a game prototype consisting of an analogue board game with digital visualization support. In the following section, the development process and research approach is described. Next, the results are presented and discussed, followed by some conclusions, among other things considering to what extent the original game specifications were possible to include into the prototype.

2. Development process and research approach

2.1 Inventory of needs to define game specifications

The starting point for the game development study was a set of previously developed specifications for planning games in general and for a sanitation planning game in particular. These specifications come from a literature review on serious games in urban and environmental planning, on sanitation planning needs, and on an inventory of existing serious games developed for water planning and management. The resulting specifications defined the principal aim of a sanitation game to be sharing knowledge about resource recovery and supporting attitude-change and collaboration with the multiple stakeholders along the sanitation service chain in both Global South and Global North settings, followed by a set of detailed specifications regarding game design, game use, game users, game development, game platform, and business model [16].

2.2 Co-design process

The study used action design research methodology in the development and prototyping of the serious game. Action design involves stakeholders from relevant organizations in an iterative design cycle, including design, testing and evaluation [17]. Organizational obstacles have been found to be a crucial issue for implementation of new dialogue planning tools [18]. Joint activities between stakeholders in policy and research facilitate co-evolution of knowledge and understanding serving to overcome such obstacles [19]. Consequently, a co-design processes involving relevant stakeholders was deemed necessary for developing and implementing an effective serious game in sanitation planning.

The co-design process was initiated through general scoping studies in Sweden and Uganda in 2017-2018. In Sweden, we met with municipal planning and sanitation officers from two municipalities. In Uganda, we interviewed key stakeholders on the national level within water, environment, agriculture agencies and municipal actors and NGOs working for sanitation. Key lines of questioning included challenges in sanitation planning; the current state and potential of nutrient recovery within the system and their attitude towards this; and the potential of serious gaming in this context. The interest for participating in a co-design process was high in Uganda, while the Swedish stakeholders preferred to be involved in a later stage when we had developed a prototype, typically due to excessive workloads in their daily activities.

The start of the actual game design in Uganda was a workshop with 30 stakeholders (Figure 1a). The workshop introduced how serious gaming could be applied in Kampala. Most of the participants were not used to playing games, so we incorporated game elements into the design of the workshop. The different discussions triggered during the workshop highlighted possibilities for gaming or collaborative-dialogue tools in Ugandan sanitation planning. In separate sessions, we tested a water recovery game [20] with sanitation NGO officers and a sanitation game [21] with 120 environmental engineering students. These game tests confirmed stakeholders' general acceptance of the use of serious games. Separate meetings were also held with sanitation officers from Kampala Capital City Authorities. Each of these meetings gave us input on directions to take with the game development. In the Swedish context, no co-design activities were carried out at this stage due to the reluctance from stakeholders to take part. Instead previous research and insights into Swedish sanitation planning served as input for game design.


Fig 1) a) Workshop Kampala b) Play-test session Kampala c) Research and design team play-testing

The next step was to engage a game designer in Sweden. A series of game development workshops with the research team and the game designer team were held from August 2018 to March 2019. The research team play-tested different versions of the boardgame developed by the game designers. Different choices of game mechanics were tested during these sessions until we had a first playable prototype. The stakeholder group in Kampala was included in the game development through SKYPE discussions.

In April 2019, two stakeholder workshops with playtests were carried out in Kampala (Figure 1b). The first workshop was with four sanitation students. One researcher facilitated the introduction and led the game play and the session was observed by the another researcher. The state of play was photographed after each round, the discussion and interaction between the players were noted, and the time of each round was clocked. Afterwards, the players responded individually to a written questionnaire about the game experience and the session ended with a group discussion. The second workshop included 20 participants from stakeholder organizations in Kampala. In order to assist players in learning the game, the facilitator guided the players through the first of the four turns and thereafter let them play more freely. After the play, participants provided individually written feedback on the game experience before the group reflected together. State of play was documented at the end of each turn. The three facilitators summarized their observations. After the workshops, we concluded that the playtests had given us valuable information about the game.

Back in Sweden, the research team presented the feedback from playtests to the game design team. At the end of May, a revised version of the game was tested with a representative from a Swedish municipality and interaction design students (Figure 1c). As in Uganda, the playtest was observed and documented by a researcher, and the players reflected upon their experience. After this, the research team and the game design team made final adjustments before printing a more elaborated prototype (Figure 2). In mid-2019, an excel application that could complement the analogue boardgame with simple digital simulations and visualizations was developed. The boardgame and the digital add-on was tested jointly for the first time in December 2019 with a group of technical graduate students. As a final step, the resulting game prototype was compared with the original game specifications.

3. **Results and discussion**

3.1 Co-design process

The co-design process was iterative, including numerous tests of playing the game in order to find the best focus, balance game mechanics, simplify the rules, and reflect on learning outcomes. The research team carried out two different co-design processes, one with the Swedish game designer team and Swedish stakeholders/students and one with just the stakeholders in Uganda. Thus, the researchers were the only connection between these processes, which means that our interpretations and impressions may have influenced the information transferred back to the game designers. Important for balanced decisions has been that we have had documentation taken from both processes. However, the lack of direct contact between the game designers in Sweden and the stakeholders in Uganda especially is a weakness. In such a situation, it might have been better to involve a game designer from Uganda familiar with the context and closer to the stakeholders.

During the scoping interviews, the Swedish stakeholders showed a strong interest in a game including more advanced simulation and real data. Stakeholders in Uganda pointed at the importance of including resources as water and energy and not only nutrients. However, in both groups collaboration and attitude-change was the most important aim for a game. When presenting the initial list of game specifications to the professional game designer, he pin-pointed an issue that we have had to struggle with throughout the process. The specifications in the gameplay category focused on soft values while the rest of the specifications were more technical. The fear of the game designer was that if we focused too much on technical aspects, there was a risk of depriving the gameplay from these softer values. Thus, the most difficult challenge has been to make design choices that maintain the most important features and to find an optimal level of abstraction to make the sanitation system recognizable for the players while still producing a game that is engaging to play.

3.2 *Resulting game prototype*

The resulting boardgame is designed for use in both Sweden and Uganda (Figure 2), including urban visualizations specific to each context. The boardgame has hexagons forming the playing area that can be selected and reshaped to fit local land use. The main activity in the game is to build sanitation systems and optimize them. Four players take on the roles of housing, treatment, farming and private contractors, each with their own actions and responsibilities, in order to cooperatively build sanitation systems and feed the inhabitants of the city. Players also have their own individual hidden agenda during for whole game, which can create additional drivers in the game. The roles are general enough to cover specific responsibilities along the sanitation chain, but still recognizable to represent different stakeholder perspectives.

Different types of resources are represented by six-sided dices that are turned to illustrate the conversion of resources through the system, including the possibilities for disease. There are unforeseen events that occur via chance cards that allow for the addition of contextual conditions and/or reshaping the narrative. A digital add-on based on Microsoft Excel simulates the degree to which the players succeed in providing sanitation services for all urban residents, recover nutrients, or have to rely on imports of food and fertilizers.

3.3 *How did the game meet the specifications?*

The starting point for the game development process was a comprehensive theoretically derived list of specifications for a serious game [15]. However, from a practical game development standpoint, it is interesting to reflect on how relevant these specifications were and how many of them were met in the resulting game. Tables 1-3 show abridged versions of the specifications we gave to the game designers, including an assessment of whether or not they are fulfilled. For this paper, this assessment only includes three of the six categories, excluding the categories for game development, game platform and business model.

Fig 2) The final boardgame prototype and pieces

Table 1: Abridged version of specifications for Game Design of a sustainable sanitation game. Full specifications can be found in Kain et al (submitted). Y = fulfilled; P = partially fulfilled; N = not fulfilled; * = in digital add-on.

CATEGORY GAME DESIGN		**Y**	**P**	**N**
Application area	-Shares knowledge about resource recovery from sanitation and supports attitude-change and collaboration between players	X		
	-Influences two sets of stakeholders: a) those playing the game and b) indirectly other stakeholders making decisions on sanitation			X
World view	- Main message: resource recovery in sanitation is a good thing, and that stakeholders need to work collaboratively towards that end.	X		
	- Focus on NPK recovery, but include water and energy		X	
	- Circular economy is beneficial	X		
	- Equity of benefits & costs between stakeholders is promoted			X
Content	*System:*			
	- Two different sanitation contexts are covered: Sweden and Uganda	X		
	- Service chain of technologies, multiple techn. exist at each level		X	
	- Illustrates the implications of different choices, e.g. possibilities to recover resources, achieve environmental & health benefits		X	
	- Simulates the performance of the sanitation system to illustrate the implications of system choices made in the game		X*	
	-Contains possibilities to design and optimize the service chain at different spatial scales, e.g. centralized or decentralized.		X	
	Roles:			
	- Multiple stakeholders along the service chain with their different perceptions regarding, e.g. health, environment, and economic gain		X	
	- Takes into account organizational, cultural and political aspects			X
Context of use	- A wide set of stakeholders can play the game, formal and informal	X		
	- Contextual conditions affecting the stakeholders and their possibilities should be taken into account, e.g. available technical and spatial resources, level of stakeholder engagement, cultural/political aspects	X		
Genre	- A strategy game or developing scenarios and coalitions	X		
	- A role-playing game	X		
	- Contains an element of simulation (*e.g* nutrient flows, etc.)		X*	
Realism	- Includes a degree of realism, based on recognizable examples of urban environments.	X		
Narrative	- A simple but realistic storyline with clear goals, and provides enough information so that players can relate to their own situation	X		
	- Narrative can be reshaped to fit local situations for relevance	X		
Data and knowledge management and transfer	- Data is managed by the game, such as the performance of different sanitation solutions/systems in the two main situations (U and S)	X*		
	- Data used in the game can be adapted to fit a specific context.			X
	- Exploration & communication of data is done by simulation	X*		
	- Collects data from the players, such as opinions, choices made, relevance of narratives, scenarios and sanitation systems/solutions			X
Data/knowledge representation	- Includes representation of key features to make the players recognize, trust and accept the game components as relevant	X		
	- Analogue and digital symbolic blocks Illustrates the system		X	
	- Contains a local perspective (e.g. local map or key features)			X
	- Visualizes pros and cons of the sanitation system resulting from the play, makes it possible to draw conclusions from the results	X*		
Interactivity	- Facilitates communication with other players through dialogue	X		
	- Communication with the game use analogue and digital means	X		

Our assessment shows that we covered many of the specification for Game design (Table 1). Still, achieving the desired content proved difficult. We struggled to balance the need for softer values (such as fluid and enjoyable gameplay) and technical realities. The complexity of the sanitation service chain had to be simplified. Use of the digital add-on allowed for basic simulations of some impacts, but still only partially fulfilled the desired simulation. Furthermore, we have not yet figured out how to achieve the desired influence of the game on the wider set of stakeholders making decisions in sanitation (i.e. those stakeholders not playing the game). Also, the question of equitable sanitation became subordinate to the message of resource recovery. Although the issue of organizational structures and cultural aspects was much discussed, these aspects were not included in order to keep the roles simple and enable gameplay. Finally, while the board pieces and chance cards can be arranged to better fit local contexts, the analogue game cannot be adapted with specific local information, e.g. a local map.

Table 2: Abridged version of specifications for Game Use the sustainable sanitation game. Full specifications can be found in Kain et al (submitted). Y = fulfilled; P = partially fulfilled; N = not fulfilled; * = in digital add-on.

CATEGORY GAME USE		**Y**	**P**	**N**
Gameplay	- Enjoyment to, in a fun and entertaining way, learn about sanitation	X		
	- Motivation to improve;a quest to overcome challenges & get rewards	X		
	- Inspiration to develop a common vision and make it happen	X		
	- Friction and conflicting/competing agendas	X		
	- Safety, breaking down barriers in a relaxed atmosphere	X		
	- Community-building to build coalitions for action		X	
Learning/social learning and collaboration	*Should support both individual and collaborative learning:*			
	- Entice learning by being challenging, entertaining, engaging, realistic	X		
	- Stimulate curiosity, opportunities for experimental learning	X		
	- Provide a platform for exchange and exploration of ideas, perceptions and positions, and possibilities to apply what is being learnt in a subsequent round of the game	X		
	- To increase the understanding of system complexity and encourage cooperation and collaboration.	X		
	- To create understanding and respect for other stakeholders' perspectives by supporting interaction and providing opportunities to try out different roles	X		
	- To encourage inclusiveness, cooperation and collaboration among players to attain a purposive transition towards sustainable sanitation	X		
Assessment	*Makes it possible to assess the outcomes of the game based on:*			
	- Level of resource recovery achieved in the developed system	X*		
	- Level of collaboration and joint learning experienced by the players		X	
	- Level of innovation in the developed sanitation system			X

We conclude that we were able to meet many specifications for the category Game use (Table 2). Yet, the current game only partially achieves specifications for creating collaboration and community-building between players. Many players commented that the game highlights the need for collaboration, but it is also possible to play the game without collaboration. This aspect can however, be included in a post-game discussion. Finally, the initial aim was to include information on technical innovations along the sanitation chain in the game. The current game does not include this information, although we may be able to include it in future versions. Regarding specifications for Game users (Table 3), we were able to fulfil a majority of specifications. It was very difficult to achieve the time requirement of a maximum two hours for gameplay, since explaining the game and post-discussion also require significant time. The game itself takes 90 minutes, but a full session needs three hours.

Table 3: Abridged version of specifications for Game Users the sustainable sanitation game. Full specifications can be found in Kain et al (submitted). Y = fulfilled; P = partially fulfilled; N = not fulfilled; * = in digital add-on.

CATEGORY GAME USERS		Y	P	N
Target audience	- Includes the collective of all those needed to be involved in a transition towards sustainable sanitation - Being part of two main groups: those playing the game itself and those interlinked through wider planning and action context	X		X
Player interaction	- Multiplayer, number of players: 3-7 - Facilitator in place, deals with issues arising from player interaction - Player roles are defined as key stakeholders involved in sanitation	X X X		
Dedication	-Accessible to inexperienced gamers and no-experts in sanitation planning. - Requires maximum two hour sessions (preferably shorter), and possible to play in multiple shorter session (maximum 1 hour)	X	X	

4. Conclusions

The study found that it was not possible to include all the original desired attributes/specifications in the final game. The game would become too lengthy and complex if all originally desired elements were included. For example, linkages to technical performance was removed in order to simplify rules and to focus stakeholder understanding on the main message of valuing resources and building cooperation. However, many stakeholders still valued the importance of including some kind of simulations with visuals to illustrate the choices made in the game. Thus, a digital add-on to the board game was developed for the possibility to simulate the performance of system built and show visuals of the improvements achieved in the service chain during gameplay. Experiences reported from the iterative testing was that the game seem to have the potential to reach many of its goals. Stakeholders found it engaging and that it stimulated creativity, allowed critical thinking, and helped to visualize and understand resource recovery loops and the importance of collaborative sanitation planning. However, the game mechanisms take time to explain and gameplay takes time. Access to stakeholders' time is limited and there was not enough time to let players learn the game in depth. Here, more skilled play-testers would have been useful to involve as co-creators of the game. It is also advisable to consider the time aspect of game development. The parallel focus on Sweden and Uganda was intended to save time, but may have delivered a weaker game. It might have been more time-efficient to design one game for each context using local game designers with understanding of the local context.

Further evaluation of the game in real planning contexts is needed to support continued development of the game and identify planning situations where application of gaming would be most appropriate. In order to investigate this, a series of game tests are planned in Sweden and Uganda during 2020. Our plan is also to develop the game toolbox and explore how different game elements can be used as stand-alone activities in specifically designed workshops, for example to explore different types of sanitation system solutions. Serious gaming in sanitation planning seems to have the potential to stimulate new ideas and open collaboration channels between stakeholders involved in gameplay. Our co-design group expressed enthusiasm for serious gaming as an innovative way for stimulating stakeholder participation. However, serious games are not stand-alone solutions, but should be embedded within dedicated planning processes to support transitions towards sustainable and equitable sanitation.

5. References

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