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MAFURIKO: Design of Nzoia basin location based flood game

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Abstract

Every 2 to 7 years, Kenya experiences a reoccurrence of El-Niño rains leading to loss of life and massive damage to property. The 1997/98 El-Niño floods affected 1.5 million persons and led to an estimated USD 1.2 billion infrastructural damage, USD 236 million agricultural damage and USD 9 million on other losses (property, soil erosion, pollution). Recent rains in October 2015 to January 2016 left 112 Kenyans dead and over 100,000 internally displaced. The Kenyan Government predictions indicate that the number of affected persons will be approximately 1,500,000, before 2018. Despite the numerous exposures to floods, Kenyan communities' resilience to floods risks is weak. Traditional crisis management approaches have not been successful in enhancing citizen capacity in flood prevention and preparedness. In addition, the past flood forecasts have not played a key role, as early warning advisories. To address these complexities, we propose a location-based game so as to create a positive learning environment and increase territory awareness, collaboration and soft skills, which are necessary for flood preparedness. Moreover, through playing the game, we hope that social learning for joint action will be enhanced. The game is known as "MAFURIKO" which is a Swahili word for floods. Through MAFURIKO, the citizens may learn basic flood prevention and preparedness procedures, may begin to see their predicament differently and may also identify opportunities which remain untapped. In this paper, we outline a theoretical framework and preliminary MAFURIKO game design specifications for the Nzoia sub-basin of the Lake Victoria Basin, in Kenya. MAFURIKO is intended to enhance the capacity of Kenyan citizens on flood risk reduction, so that they can work with the Kenyan Government to prevent and prepare for future floods. Future work will entail completion, staging and application of the location based game.

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Keywords: Serious Gaming; Location-based Games; Flood Preparedness; Citizen Participation; Natural Disasters; Climate-change; Deep Uncertainty; Kenya; Lake Victoria Basin; Nzoia Basin; Water Management

1. Introduction

A serious game is "any form of interactive … game for one or multiple players to be used on any platform and that has been developed with the intention to be more than entertainment" [1]. Serious gaming is an effective teaching tool because it simulates an environment where complex multi-criteria problems that involve multi-decision makers, can be resolved. Through conventional teaching methods, such complex problems are often represented or perceived to involve a single objective and a single-decision-maker. This leads to poor solutions that fail to address the core problem [2]. In addition, serious games can act as a bridge and facilitate dialogue amongst citizens and between the citizens and policy makers.

Flood preparedness skills include territory awareness, knowledge of the flood prevention and preparedness procedures, collaboration and soft skills [3]. A branch of serious gaming that has in the past proven to be effective in enhancing community capacity in disaster preparedness is location based gaming. Location based games are "games in which the players' immediate surroundings and the locations they visit result in a direct influence on the outcome of the game" [4]. Location based gaming is considered more effective in building capacity on flood preparedness because the physical and virtual realities are merged in the

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game. This results in increased territorial and situation awareness, since real places are directly connected to the virtual space. Playing the game involves exploring ones environment. As a consequence, the game increases location awareness of the players with their environment and other community members who are playing the collaborative game. Since the virtual world is merged with the physical world, the reputation you gain in the game translates to the reputation gained in real world, resulting to higher levels of motivation to play the game and the creation of stronger horizontal social networks.

In this paper, we outline a theoretical framework and preliminary MAFURIKO game design specifications for the Nzoia sub-basin of the Lake Victoria Basin, in Kenya. The paper is structured as follows, Section 2, describes the vulnerability of the Kenyan citizens to floods and the factors that increase their vulnerability. Section 3, outlines the theoretical framework in which the game is embedded. Section 4, reviews literature on location based gaming in the area of flood prevention and preparedness. Section 5, describes Mafuriko, a Nzoia sub-basin flood prevention and preparedness location-based game. Finally, in Section 6, we make our concluding remarks.

2. background

Floods are a very common disaster in Kenya that occurs every two to seven years. The most recent occurrence was in October 2015 to January 2016, where 112 person's died and more than 100,000 were internally displaced [5]. Before this flood, there have been many floods, but the most significant flood was the 1997/98 El-Niño flood. The 1997/98 El-Niño flood affected approximately 1.5 million people in Kenya and there was loss of lives and immense damage to property. In addition, there was an estimated 1.2 billion damage of roads, dykes, water supply structures, buildings, communication systems and other infrastructures. The damage to the agricultural sector was estimated at USD 236 million and USD 9 million on other losses (property, soil erosion, pollution) [6, 7].

According to Government estimates, flood incidence will increase, in the near future. It is estimated that there will be an increase in annual rainfall until 2030 [7, 8]. The areas that will receive the highest rainfall are the flood prone areas in western Kenya around Mount Elgon, Elgeyo Escarpment and Cherangani Hills (this flood prone region is the drainage basin for River Nzoia, which drains into Lake Victoria in Budalangi District) [7, 9]. It is estimated that in the period 2016 to 2018, El-Niño floods will affect over 1,500,000 people. One-third of these people will be refugees in two refugee camps, Dadaab and Kakuma (mainly Dadaab). These floods will not only affect lives; learning will be interrupted as schools get flooded and roads will be damaged, cutting off some communities from the rest of Kenya. There will also be crop damage in some areas and water-borne diseases will escalate [9].

The communities in the flood plain are extremely vulnerable due to a number of factors. Community perceptions on the nature of floods is a major hindrance to efforts aimed at enhancing their disaster risk reduction and preparedness skills. Nyakundi (2010) carried out an assessment on community perceptions in the Lake Victoria basin and in his paper he concludes that even though this community has experienced multiple flood events, these events have not improved their coping strategies. When Nyakundi (2010) interviewed a number of the community representatives, he realized that citizens living in the high risk area perceived floods as "inevitable and fairly unpredictable, … limiting scope for action and response" [10]. Due to past floods, communities have resulted to construct semi-permanent homes, so as to reduce the property loss and damage, in subsequent floods. Unfortunately, this adaptation strategy makes them more vulnerable, because the semi-permanent houses cannot shelter them from future floods [8]. Consequently, these communities resulted in entirely relying on the Government to facilitate the flood response and recovery process and the Kenya Meteorological Department (KMD) to provide early warning advisories.

KMD faces a number of challenges that affect the accuracy and real-time transmission of predictions and early warning advisories. First, the KMD rainfall stations in Nzoia are not sufficient for the collection of the needed data. KMD had about 2000 rainfall stations that measure only rainfall. Unfortunately, most of these stations had to close down due to limited resources for data collection and repairs. Currently there are approximately 600 rainfall stations. Second, due to the poor spatial coverage and insufficient observational networks, KMD has experienced difficulties in the provision of location specific forecasts. Unfortunately, without location specific forecasts, the early warning advisories cannot be taken seriously and acted upon. Third, KMD lacks the required state of the art data analysis and integration products. This has affected the accuracy of their forecasts. Fourth, KMD faces a dissemination challenge; it has to rely on many other partners to facilitate the dissemination of the information (predictions and warnings), on real-time basis. This is rarely done. As a consequence, poor dissemination has a largely decreased the utility of the data. Finally, most of the products are produced in a format which is technical and not customised to the end user's needs and language [11]. There is a big communication gap between the developers of the early warning advisories and the end users. All the afore-mentioned challenges need to be addressed in order to increase the utility of the KMD information by end users.

The challenges faced by KMD increase the vulnerability of the communities living in the floodplains. The early warning advisories are not reliable nor accessible in a form that supports flood prevention and preparedness. On the contrary, the Nzoia sub-basin citizens have placed their trust in the KMD system and done very little to enhance their individual adaptive capacity. Unfortunately, KMD, has not engaged the citizens as scientists or sensors of the sub-basin system. KMD has treated the citizens as end-users of its products, which is a very low level of engagement, that usually does not resolve complex problems [12]. In addition, past disasters have led to very little collaborative actions between the citizens and KMD. One explanation may be that when the disaster occurred, the people who were expected to work together to reduce the effects of the disaster barely knew each other and had not had the opportunity to work together and develop trust. Regrettably, "the disaster (did) not wait for them" [13 pp. 307].

To address the above challenges, the Nzoia sub-basin citizens need to be prepared for future floods. Since most of the citizens in the flood-plains believe that the floods are inevitable and there is very little they can do to prepare and prevent them, there is need for new learning tools that challenge their current perceptions and encourage more adaptive thinking. Serious games, if well designed and applied, can facilitate the change of perceptions and lead to social learning. Instead of waiting for the disaster to occur again, so that the communities can learn from it, we decided to design a game known as MAFURIKO. MAFURIKO simulates the disaster situation and exposes the existing limitations to citizen disaster prevention and preparedness. Through the application of the game, we want to assess whether Mafuriko will enhance flood preparedness.

3. Theoretical Framework

Through serious games, players can enhance their cognitive abilities (McGonigal, 2011), communication and collaboration skills and gain first-hand experience on roles, problem areas and social contexts that they would not be exposed to, in reality [14, 15]. Gee (2005), explains that through an avatar or any other representation, players lose themselves and plug into another self. This process enables them to be less restricted, as they act this new role. The opening of oneself to act the persona of another self, creates a safe and positive environment for challenging old perceptions, skills and values and acquiring new ones [16].

The primary purpose of serious games it so solve complex problems through an integrated decision making process. The problem solving process mainly entails repeated rounds that lead to some failures and successes. This repetitive process enables one to spot the pattern that led to success. Through successive discoveries, the player makes decisions, gains more confidence to make similar decisions and learns from successes and failures [17, 18]. Through an iterative process of managing challenges, which successively increase in complexity, players learn to master the game. Mastery is what drives people to play multiple rounds. Mastery leads to deep learning [17].

McGonigal (2011, p. 21), identifies four key elements of a game that enable them to engage players for a long period of time [15]:

1. A captivating goal that keeps players focused on the challenge, motivates the players to continue playing and makes them to be more persistent to master the required skills.
2. Voluntary participation of players in contrast to the real life learning systems, builds persistence. This is because when players voluntary play a game, they perceive it as entertaining, even when the challenges become very complex and hard to solve.
3. Game rules that encourage players to come out of their comfort zones and explore new territories that they would normally not do in real life situations. In many instances, when the players leave their comfort zones, they develop better solutions and bring new innovations to the game.
4. A strong and continuous feedback mechanism that informs the players where they are and what remains to reach their goal.

Beatty (2013), McGonigal (2011, p. 21), Gee (2005, 2007a), Squire (2006) and Steinkuehler (2004, 2006) identify the following learning principles of an electronic game [19]:

1. **Multi-layer phenomena**. Complex multi-actor systems problems cannot be solved by one solution and one decision-maker. Understanding of complex problems is a long and tedious process that requires not only the relevant skills but also time, patience and perseverance. Fortunately, through a game, this complexity is introduced in layers and experienced through the player's strategies, choices, actions and the results of his or her actions. The game disentangles the overlapping layers of the complex problem into small portions that can be grasped at that moment in time and enables the player to master skills to address the problem through iteration. Thereafter, after mastery of the basics, more layers are introduced in successive rounds [20].
2. **Skills as strategies**: Games link the skills that are being mastered to the strategies the players have to employ and ultimately to the goal. Since the players have a captivating goal, they acquire the necessary skills and improve their strategies as they work towards their goal [15].
3. **Co-design**: through gaming players are never passive actors, they are always the active actors who are making decisions that have huge impacts [15].
4. **Designers and Builders**: Games like MINECRAFT create a platform where the players can contribute to the design of something which may inform planning and decision making in the real world [14].
5. **New Identity Construction**: New identity construction is the process of leaving oneself in the real world and plugging into a different self in the virtual world. It is a very strong element of deep learning [14, 16]. Serious games effectively facilitate the process of identity formation and development so as to stimulate change of values and perceptions.
6. **Affinity Space**: Players can enhance their social networks through playing collaborative games [20, 21].
7. **Mastery of Skills**: The main motivation in gaming is mastery. Game play normally takes place over extended periods of time, in an iterative manner, which leads to deep learning [15].

8. **Cycles of expertise**: Repetitive actions aimed at mastering the game leads to specialisation in a certain profession.
9. **Information on demand and just in time**: In gaming, players get information and feedback in real-time, which is very effective in decision-making [15].
10. **Meaning as action image**: Players learn more through the game experience, compared to words or concepts [15].

Beatty (2013) synthesised the previously explained game-based learning aspects and developed a four layer framework. Each layer describes a different dimension or scale of the game-playing experience [19]. The four layers are:

1. **Micro-level game layer**. This is the level of detail and its focus is on a number of game elements that include: a goal that captivates the players; the specific challenges / puzzles / obstacles that players have to overcome; avatars that the player can control; the effects of players actions; how iteration is constructed and many more.
2. **Macro-level game layer**. This is the theoretical aspect of the game that focuses on how the players experience the virtual world and the storyline.
3. **The builder meta-game layer**. This layer concentrates on how the game facilitates player's collaborative design and subsequently imparts design knowledge and skills.
4. **The social meta-level game layer**. This layer looks at the social interactions between the players and assesses group formation and social identity construction (Fig. 1.b).

The four layer frameworks follow a similar generic layer template. The game-layer that we would like to use for the design of the MAFURIKO game is the social meta-level game layer (Fig. 1.b). This is because the game is aimed at increasing citizen collaboration, soft skills, communication skills and situation awareness skills. However, all the other layers are relevant and will also inform the game design decisions, so that we develop a game that may lead to deep learning through challenging old perceptions, skills and values and acquiring new ones.

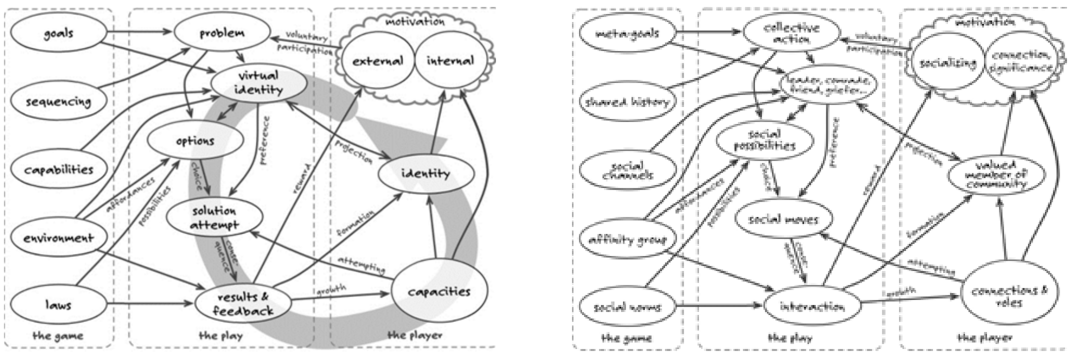

Fig. 1. (a) Left: The identity loop shown on the generic framework layer; (b) Right: The social meta-level game layer, focusing on social experiences within the affinity group, and on forming a meta-game social identity (Source: Beatty (2013)).

The generic framework has a feedback loop known as the identity loop. In the identity loop, three identities meet and interact, real-life, virtual and projective identity. The real-life identity depicts the actual identity of the player in the physical world. This includes the player's actual capacities, perceptions and values. The virtual identity is the new constructed self that the player has developed and plugged into, including its capacities, aims and values. The last identity loop is the projective identity that emerges when the real-life and virtual identities merge. This fusion enables the player to infuse his real-life values and aspirations into the virtual identity. In addition, the player's real-life identity develops, as it fuses with the virtual identity [19].

Based on the afore-mentioned, we can state that serious gaming enhances deep learning. It is a new approach to learning that is distinct from the other forms of learning. This is because, many conventional forms of learning:

1. focus on simple problem solving approaches that are not effective in the current complex and deeply uncertain world.
2. are no constructively aligned. The teaching goals are not aligned to the teaching and learning activities and the assessments.
3. perceive students are passive recipients of the knowledge provided in lecture sessions.
4. focus on the lower order learning (understand, remember and apply). Very little focus is on the higher order learning (analysing, evaluating and creating (co-design)).
5. barely impart design skills because they mainly focus on low order learning.
6. focus on the real-life identity and go through numerous attempts to improve learning disabilities that they perceive in the real-life identity. Very little focus is on allowing students to create and plug into a virtual identity that may help to improve on their current self through a more friendly and safe learning environment.
7. possess limited opportunities to expand ones social network outside the physical learning environment or the online class.
8. focus on specialisation and a student's "calling", which limits learning, exploration and innovation.

9. barely lead to a mastery of skills because every day the teacher introduces new things and the iterative process is either lacking or not well developed, as in a game setting.
10. use outdated information and the feedback mechanism is too slow and inefficient. Feedback on performance is usually after a long time when a student has mastered the wrong thing. Regrettably, unlearning these wrong skills, takes a longer time than learning.
11. rarely focus on learning through experience, therefore the students learn much less than in serious gaming.

In the application of MAFURIKO, we will seek to assess whether the framework developed by Beatty (2014) can support the design of a location based game aimed at enhancing learning on flood risk reduction [19]. We will seek to incorporate all the positive benefits of serious gaming, so as to ensure that the Nzoia sub-basin citizens experience deep learning.

4. Review of Location Based Games

In addition to the Beatty's (2013) framework for learning, we took account the basic elements that comprise a real life flood situation. The context of a flood in Nzoia sub-basin is characterized by: (a) unexpected and fast occurrence floods, mainly in the night when the oil lamps are off and people are asleep. To survive a flood, one has to make fast decisions (for example, whether to relocate, who to help, where to take refuge, what to carry). These decisions have major impacts but have to be made within a very short time span. (b) the urgent need to communicate and collaborate to survive. In the fishing communities, the flooding may occur at night when the men and boys are fishing, thus the women need to work together to minimize the flood damage. Effective flood management requires good communication and collaboration skills; (c) the need for location awareness. Floods normally block roads, passages and break bridges. Therefore people need to have a good knowledge of their environment so that they make quick decisions to change directions, when they come across a road block, a broken bridge of a flooded area [3]. Therefore one needs collaboration, territory exploration and soft skills (for example communication, decision-making and stress management skills), to effectively prepare for a flood [22]. One of the best ways to achieve this form of training is through the design and application of a context and location-aware application.

We therefore assessed the current location based games and found one that is close to what we intended to design. The games range from very sophisticated games like INGRESS [23] and GEOCACHING [24] with so many players globally and with national and international joint efforts, to very simple games like FLOODSIM [25]. We could only find three location based games in the area of flood protection: FLOODSIM, LEVEE PATROLLER [26] and FLOODED [22]. FLOODSIM was developed after the 2007 floods in the United Kingdom as an awareness raising LBG on the increasing risk of floods. It also focuses on preventative policies and government interventions including expenditure. Levee patroller is designed to train levee inspectors on what to look for when carrying out inspections. Flooded is a game for training citizens on flood preparedness. Its design encompasses the three elements necessary for effective disaster management: emotional intelligence, collaboration and location exploration. Thereafter, we checked for the presence of the three elements for disaster management in the three games (Table 1) and only Flooded contained the elements we were looking for in a LBG.

Table 1. Analysis of Flood Location Based Games.

Game	Emotional Intelligence	Collaboration	Location Exploration
Flooded	yes	yes	yes
FloodSim	no	no	no
Levee Patroller	yes	no	no

Based on the above analysis, we decided to use FLOODED as the starting point for the design of MAFURIKO. Fig. 2 illustrates some of the screens for the FLOODED LBG. The game is based on four challenges: (1) learning flooding dangers; (2) learning decision making at all stages of the flood (prevention, preparedness, response and recovery); (3) learning how to monitor and explore your environment; (4) enhancing your emotional intelligence and collaboration skills.

5. MAFURIKO

5.1. Study Area

The study area is the Nzoia sub-basin (34.4°, 35.6°E/ 0.1°,1.3°N) including the upper reaches of the Nzoia river, in the Lake Victoria Basin (Fig. 3). The study area is approximately 10,156 square kilometers. River Nzoia is a highly seasonal river (ranges from 20 m3/s to 1100 m3/s [27]) with its peak in May and September, during the two rainy seasons and due to rainfall in the higher regions of Mount Elgon and Cherangani hills. The River's upper reaches (135 to 257 kilometers) are densely populated and part of it consists of protected forests. The middle reaches (20 to 135 kilometers) is more populated at the valley bottom by subsistence crop and livestock farmers. The last 20 kilometers consists of a densely populated flat area with a lot of economic activities (fishing, crop farming and livestock rearing). The area is covered by clay, loamy and sandy soils. In the lower reaches, the river's channel width increases from 50 to 70 meters as the bank height reduces significantly, thereby leading to spill overs and when the flow is high, flooding.

Fig. 2. Screens from FLOODED (a) main screen; (b) player placing sandbag wall; (c) player dead (d) player revived. Source: Mannsverk, 2013 [3].

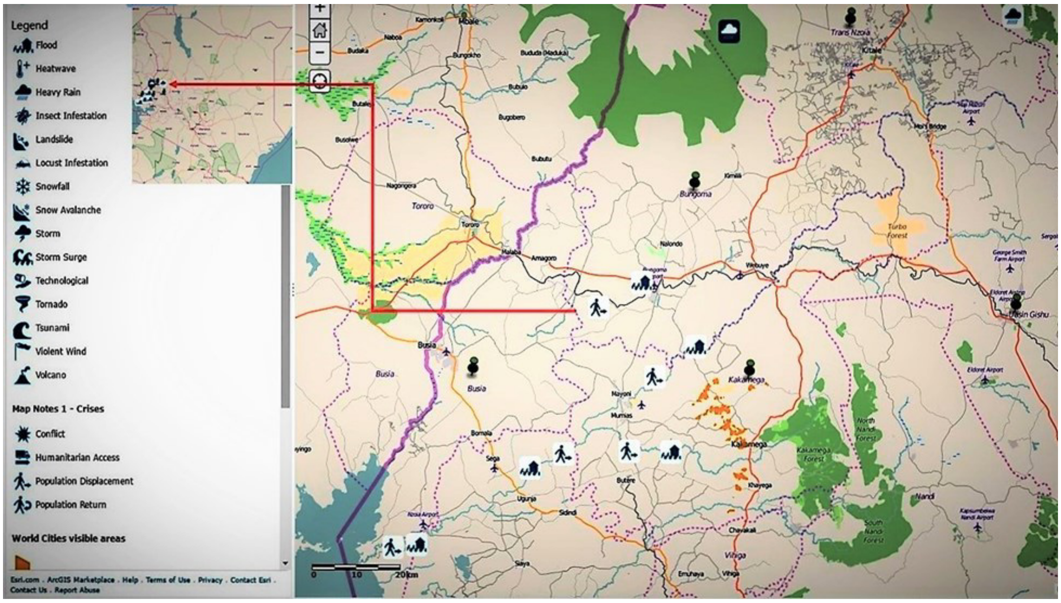

Fig. 3. Location of the study area (Upper and Lower Nzoia River basin) with indications of flooded areas, areas with high rainfall and places where the population is normally displaced during floods. The game will be applied in the Uasin Gishu, Trans Nzoia, Kakamega, Bungoma and Busia Counties, as illustrated in the map with the green pins.

5.2. Purpose of Game

The purpose of the game is to enhance learning on the dangers of flooding in the Nzoia sub-basin; to support decision making at all stages of the flood (prevention, preparedness, response and recovery); to increase monitoring and location awareness skills; and to enhance citizen's emotional intelligence and collaboration skills.

5.3. 1.3. Game Specifications

The game is a Nzoia sub-basin mobile phone location based game for citizens that is simple, fun to play and challenging. Flood Management is a spatial based issue because each locality has different water resources, needs and objectives. Therefore it would be more enriching for a game to be designed that enables the players to play within their locality. The game is intended to focus on three components:

1. A **WIKI** that enables citizens to collectively develop an information package with useful information on their particular area. The package will include information regarding the history of the area, tourist attractions, available water resources and their exploitation, related local businesses and available accommodation. This wiki is aimed at increasing playing of the game by local communities. The citizens can populate the wiki and upload photos.
2. A **LOCATION BASED FEEDBACK MECHANISM** that facilitates the citizens to give their opinion directly on anything in the area. The mechanism should enable citizens to stop anywhere and provide information to the water managers. This should be related to flood management and aimed at informing decision on the flood prevention and preparedness. Each message has a time-stamp and coordinates. The feedback mechanism can also act as an early warning advisory. The opinions are geo-located so as to find out if there are areas where there are strong opinions about a particular issue. The feedback mechanism should be designed for the collection of opinions and also as an early warning advisory to the decision makers.
3. A **LOCATION BASED GAME** designed to create awareness on the value of flood management and promote citizen preparedness to flood conditions. The game will have a minimum of four challenges as illustrated below:

- **CHALLENGE 1**: Sensitization on the dangers of unilateral actions and the value of flood management. Since the Nzoia sub-basin has suffered from extreme land degradation, it is vital to raise awareness on the need for collective management of the area so as to avoid history repeating itself. Players could collaborate to plant trees on the de-forested areas. While they plant trees, they should provide sustainable solutions for the food and energy that will be lost through the land use conversion. The players will be required to physically walk around the area in order to plant the trees. The game will develop rules on land use conversion to forestry and its relation to flood management.
- **CHALLENGE 2**: Importance of doing the right thing in terms of water conservation and the overall flood management (before, during and after the floods). The citizens should be aware of the available water resources in their area and how they can manage it so as to be better prepared for floods. The challenge should also focus on the right actions to be taken to ensure energy and food sustainability within the locality. The players will know the geography of the area, the flood prone areas and the areas that are barely affected by droughts. In addition, the players will know the frequency of the floods. They will also need to be prepared for the erratic rainfall (El Nino). Players will be expected to take smart actions to increase their resilience to floods.
- **CHALLENGE 3**: Importance of territory monitoring / exploration and providing early warning advisory. The monitoring will be based mainly on water quantity and forest cover. The players near the rivers can monitor the water levels and if they rise they can alert the players near the forests to increase the forest cover (challenge 1). The players near forests can act as early warning advisories if there is a change of land use that they have not been aware of which might impact on water quantity. The players near water bodies can alert others on the change in water use that will impact on other sectors like agriculture, tourism and energy. All players in the flood plains can monitor floods using existing local and scientific knowledge and the water levels in the rivers.
- **CHALLENGE 4**: Importance of soft skills like collaboration and communication in the integrated management of water resources. The game will be designed so that players can easily identify the locations of other players and use that information to collaborate so that the outcomes can be improved. An integrated voice-over IP (VoIP) solution may be better than a text system. This is because in previous games text from other players were ignored when there were a time constraints and thus collaboration was not enhanced [3].

The game design applications will be based on available tools, cost implications and apps online. A list of probable design applications include: ArcGIS, Python, Facebook SDK 3.0 for Android, Smart Sheets, Google Maps Android API v2 and Google Cloud Messaging (GCM)).

6. Construction of references

Over 1.5 million persons in the Nzoia sub-basin are at risk of losing their lives, livelihoods and property due to climate-change induced disasters. In addition, communities living in the over-populated Nzoia flood plains are extremely vulnerable because most of them live, work and farm in the plains, practice poor land use practices and construct weak housing structures. In most of these geographical regions, there are weak Government constructed flood defense infrastructures that are rarely maintained. Furthermore, many of the community members perceive the floods as unpredictable and inevitable. Unfortunately, this perception has stopped them, for so many years, from taking joint action to increase their flood prevention and preparedness strategies. Consequently, they have resulted in entirely relying on the Kenyan Government to facilitate the response and recovery process and to provide early warning advisories on oncoming floods.

The paper adopts a theoretical framework and initial design specifications for the MAFURIKO game. We hope that MAFURIKO will define a new generation of citizen capacity development methodologies where location based games are used to enhance capacity on flood prevention and preparedness; sharing collective intelligence about events and places; supporting a shared location awareness; and implementing new approaches to electronic participation (eParticipation).

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