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A Serious Game to Inform Young Citizens on Canal Water Maintenance

Yoeri Appel, Yordan Dimitrov, Sjoerd Gnodde, Natasja van Heerden, Pieter Kools, Daniël Swaab, Nestor Z. Salamon, J. Timothy Balint, and Rafael Bidarra(✉)

Faculty of Electrical Engineering, Mathematics and Computer Science, Delft University of Technology, Delft, The Netherlands
R.Bidarra@tudelft.nl

Abstract. In order to support the creation of sustainable and healthy ecosystems, citizens should have knowledge of the necessary maintenance needed. For example, they should be aware of the challenges of maintaining proper urban surface waters, so that they can take on a responsible and proactive role. Ideally, citizens should acquire this knowledge from an early age. We describe the design, implementation, and evaluation of the serious game *Hydro Hero*, aimed at forming and reinforcing this awareness and reasoning. Hydro Hero is an infinite runner game with extended minigames, which show both *what* should not be on the canals as well as *why* they should be removed. We assessed the ability of Hydro Hero to teach young children about canal maintenance by combining a questionnaire with open-ended play-testing sessions at a science museum. On average, players were able to improve their ability to justify why certain items should be removed or left in a canal. It has not been fully confirmed that Hydro Hero conveyed this specific knowledge, due to the absence of quizzing beforehand. However, given the high participants' engagement, we consider the game to have contributed to their awareness about the importance of canal cleaning for a sustainable urban environment.

Keywords: Urban water · Educational games · Behavior change

1 Introduction

Good water management is increasingly important for sustainable ecosystems, in particular for urban environments. Moreover, clean surface water is essential for drinking water, recreation and most plant and animal species. With rapid growing urbanisation, water quality and quantity is under threat. For a sustainable future, water management is especially crucial in the Netherlands, due to its large number of rivers, canals, ditches, levees and lakes. Hence, urban sustainability does not only extends to solar panels and windmills, but also about the mindset and behaviour of citizens. Many people in the Netherlands have limited knowledge about canal cleaning and canal maintenance. The water boards that conduct canal maintenance have tried to make people more aware about the

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topic, but it has had little effect on public knowledge [10]. This is undesirable, since the general public is also responsible for some of the problems to canal sustainability [5].

Knowledge is important in order to change behaviour: in general, people do not change their mindset and behaviour if they are able to ignore the issue. Therefore, we propose a game to teach children about the importance of water quality on canals. Our research question is:

> "Can children improve their knowledge about canal water maintenance trough playing a serious game?"

Here, knowledge has two aspects: (i) the static knowledge on *what* is favourable and unfavourable to a canal, and (ii) the reason *why* unfavourable items need to be removed.

2 Related Work

Designing educational games for children has been a matter of research for quite some time. Romero and Barma [8] for example, identified many educational possibilities in games for children. Gamification has been often used to enhance learning. This includes digital games, provided certain prerequisites are met [1]. However, the evidence to substantiate this is mainly empirical [3]. A study by Wrzesien and Raya [12] found no significant correlation between children who were taught via games and the control group. They reported, however, more joy, engagement and participation from the children who used serious games. Girard et al. [3] suggest that more empirical research is needed when examining gamification for learning, which is aligned with the topic of this paper.

Various quiz-based games and questionnaires have been deployed as well. For example, with the German game *Prosodiya*, parents and children are tested by answering subjective questions, mainly about the appreciation of the game, while the game assesses a person's presumption about the knowledge that has been gained [4]. Player's motivation has also been analysed. For example, a leader board can work well as a motivator when continuously playing a game [6, p. 34]. When players are only motivated by the reward built into the learning game, they oftentimes do not retain much information [6]. Therefore, it is essential that the player is motivated in the game, by tasks that induce learning. In another paper, Bußwolder and Gebhardt [2] found no significant correlation, between the players' motivation and their performance. Therefore, motivation only affects the attractiveness of longer gameplay sessions.

Furthermore, work has been done in teaching and explanation methods. Wallner et al. [9] empirically concluded that children have the tendency to rush past tutorials. In our game, we took the decision not to implement separate tutorials, but instead make the game self explanatory via minigames.

3 Game Design

Hydro Hero is built around the concept that the player needs to clean and maintain a canal. The player does this by controlling an avatar that has to collect entities that should not be in the water or on the banks. The avatar has a steadily increasing velocity along the direction of the canal. The avatar's lateral movements are limited in range and in speed. Such mechanics makes the game challenging while still being easy to comprehend, in an attempt to lessen the stress of the overall experience.

The canal is an artistic illustration, inspired on a Dutch *boezem* and a *polder* canal. The movement of the entities gives the impression that the avatar is moving along the canal, instead of the water flowing towards the avatar. During the game, the current score is shown in the left top corner, and in the right top corner the three lives, in the form of hearts, are shown. Figure 1 shows a screen capture of the game, illustrating the main visual components.

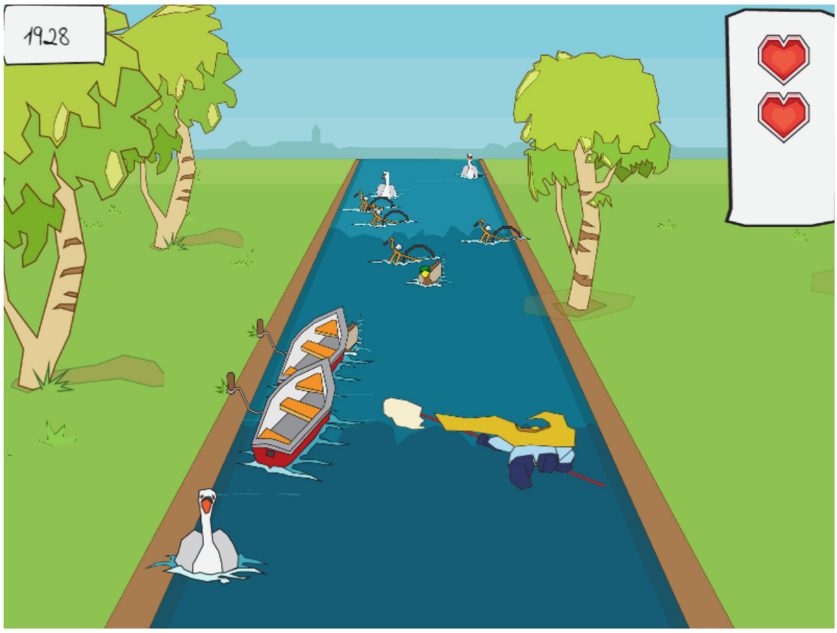


Fig. 1. Overview of the game. The avatar flies and removes items that are harmful to the canal and banks, while avoiding positive environment entities.

A moderate skill set has to be developed to guide the avatar to collect the objects that do not belong in a canal, called *pickups*, as well as avoid those that do belong there, called *obstacles*. Table 1 lists the in-game *pickups* and *obstacles* and the reasoning for such classification. The player initially does not receive any clues about the nature of the items, either pickup or obstacle. Therefore, the player has to consider what item they have to pick up. The learning goal

for the player is to realise that they should remove malicious items from canals, as well as avoid items that belong in or around canals. Later, new pickups are introduced incrementally and explained via minigames.

Table 1. Pickups and obstacles in Hydro Hero

Item	Interaction	Reason
Musk rat	Pickup	Musk rats make holes in levees which weakens them and is a competitor to native species
Garbage bag	Pickup	Perilous to water ecology
Plastic bottle	Pickup	Perilous to water ecology
Duckweed	Pickup	Blocks sunlight and is therefore perilous for water life
Reed	Pickup	Can overgrow large sections of the canal and increases friction of transporting water
Bike	Pickup	Blocks boats
Boat	Obstacle	In general forms no problem to canal
Swan	Obstacle	In general forms no problem to canal
Duck	Obstacle	In general forms no problem to canal
Trees	Obstacle	In general forms no problem to canal and surroundings

During the game, the player loses a "life" for every obstacle it runs into. After losing three lives, the game is finished. By giving players more lives, they will be able to progress through the game more easily, instead of failing at the beginning. Without being able to interact with the subsequent tasks, they would thus fail to meet the learning goals.

Players can enter their name when the game is over, possibly to be featured in the top 10 score list. In addition, the player is also motivated to play the game again via a prominent replay button and attempt to achieve a higher score while learning more about canal maintenance.

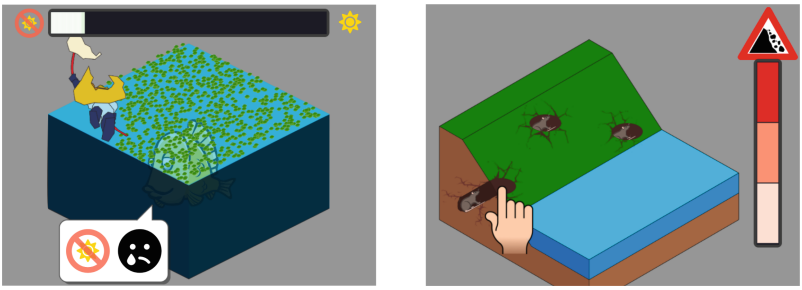
3.1 Minigames

For the scope of this project, we focus on the "healthiness" of a canal. After the initial experience relying only the player's previous knowledge and common objects (e.g., ducks and garbage bags), the game starts with teaching children which items do not belong in canals. Also, it is equally important to teach them the reasons why those objects can be harmful to canal health and maintenance. To assist in such explanatory task, we implemented a variety of minigames, showing in an engaging way the positive effects of removing harmful objects from the water.

The minigames are simplistic: the player only has to perform a basic task. Executing this task reveals the reason why the object is harmful for the canal

health. Every new pickup item is first introduced with a minigame; only after a minigame is finished can the player continue to the main game. A combination of a minigame and a section of pickups to the next minigame is called a level.

Two minigames are shown in Fig. 2. In minigame Fig. 2a, the aim is to remove duckweed with a net. The explanatory balloon shows why the duckweed is bad for the canal: it blocks the sunlight. While the duckweed is getting removed, the colour of the canal turns brighter. When enough duckweed is removed, the smiley face turns happy and the red circle around the sun is removed. In minigame Fig. 2b the aim is to hit muskrats, while they appear out of their holes. The player sees cracks disappearing, mitigating the danger of levees collapsing.



(a) Removing duckweed (b) Catching muskrats

Fig. 2. Example of two minigames that introduce new pickups. Left: the aim is to remove duckweed, that blocks sunlight into the canal. Right: the goal is to catch muskrats that build holes in levees. (Color figure online)

In our evaluation, we found that the age and prior knowledge of the players had an effect on the players' understanding of why the minigames were included. Furthermore, despite the tempo of the minigames, players were able to understand the concept being conveyed by the game. Finally, after completing a minigame, players has to press a 'Continue' button before proceeding to the topic streak. This consciously reinforces the connection between the main mechanic and the minigame. Figure 3 shows the complete game flow diagram.

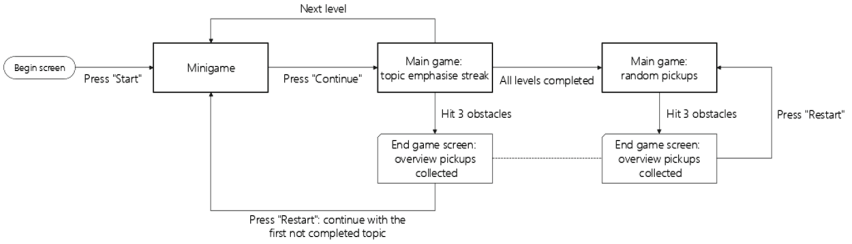


Fig. 3. Game flow: one *minigame* and one *topic emphasise streak* form a level.

3.2 Engagement Mechanism

Many infinite runner games spawn a variety of items from the start, so that players grab entities (either by intuition or by accident) which they believe are possible to be picked up. As a result, without further interaction, players will make no significant progress and, above all, they may fail to capture the rationale behind each item. For Hydro Hero, this would be undesirable and counter-productive. Therefore we opted for deploying after each minigame a *topic emphasise streak level* (see Fig. 3), in which only the specific pickup, together with some obstacles, are presented to the player. This proved to be an useful approach. Many players decided at some point to try out one of these pickups, and realised the nature of the item. Players who persisted in not picking up these items, unavoidably end up hitting one, find it out then. A finish flag is shown after a minimum amount of pickups, and the cycle starts over for a new pickup.

After all the levels have been played and all pickups introduced, the game advances to the final stage: all pickups and obstacles spawn randomly. The player now stays engaged with the game and gets constantly challenged with an increasing navigation and spawn speeds. This goes hand-in-hand with the theory of Wouters et al. [11]: surprises have a positive effect on learning when existing proportional reasoning is included. Players who reached this phase should have a basic understanding of whether an item should be removed. This phase reinforces the ideas through repetition - and competition for high scores.

4 Validation

We implemented Hydro Hero as a browser-based game using Phaser [7]. Relying solely on HTML5 and JavaScript, it prevents players from needing to install additional libraries, which allows the game to reach a wider audience.

In practice, we tested our hypothesis in two ways. Firstly, we tested our approach with non-evaluated playing rounds. This testing delivered solely anecdotal evidence, and was merely used for development of the game. Attention was given to how engaged players were and whether they understood the game. Lately, during the play testing, all the elements of the game were looked at and the engagement, inquisitiveness, amusement, and confusion of players was noted. Components of the game, such as the minigames, were also tested separately to find out its influence on the gameplay and the ability in teaching the player. In this example, the minigames were turned off for certain players and the reaction to new objects was analysed.

Given the nature of the testing place - a public science museum, involvement of the parents/guardians or siblings/friends could not be prevented during the tests. This, however, reflects actually the real world playing, and was therefore not regarded as a problem.

Overall, minigames seemed essential in making clear both what items players had to grab and the reason to do that. The topic emphasise streaks made it even more clear the items that had to be picked up. Without these streaks, players were generally more confused about the function of all items.

The conclusive testing of the prototype was done with a fixed question quiz. The players were quizzed before playing the game first. Five closed questions with the options 'yes', 'no' and 'don't know', were orally asked in order to access the knowledge of the player prior to playing. After the game, the same questions were asked again. However, at this time, if the player gave an answer (right or wrong) that an item did not belong in/near a canal, four plausible options, as well as a 'I don't know'-option were presented to justify the reasoning (Fig. 4).

Prior to the game:
Does a lot of duckweed belong in the canal?

After playing the game:
Does a lot of duckweed belong in the canal?
Why doesn't it?

Fig. 4. Example quiz question. Answer options accepted 'yes', 'no' and 'I don't know', as well as plausible reasoning choices.

5 Results and Discussion

The time played was on average around five stages in six minutes. Overall, players seemed to highly enjoy the game. Next, we applied the quiz described in Sect. 4 to measure the effectiveness of our approach. Results are evaluated on (i) the improvement in static knowledge and (ii) to what extent the players knew about the reason why certain items do not belong in a canal. In total, 20 children participated on the evaluation; the ages are listed in Fig. 5 (right).

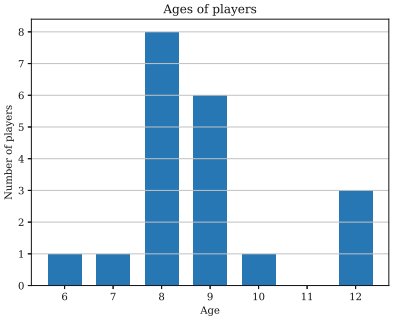


Fig. 5. A child playing the game and the age distribution of the participants.

The improvement of static knowledge (does/does not belong) (i) was tested with the difference in scores of the closed questions prior (X_p) and after (X_a) playing the game, where X_p and X_a depict the sample scores from the user testing. The results are plotted in Fig. 6 (left). The average difference $\mu_{\Delta x}$ was +1.55, and the standard error $\sigma_{\Delta x}$ 1.00 of the test with n = 20. The null hypothesis H_0 was that players did not learn from the game, so $H_0 : \mu_{\Delta X} = 0$. Then $H_1 : \mu_{\Delta X} > 0$. Via a student t-test, a right side p-value was found of 6.452E–07. Therefore, H_0 is rejected and it is likely that H_1 is true.

The reason why certain items are unfavourable for the canal (ii) was measured via the ratio between the correctly selected reasons (R) and the correctly answered closed questions from items that were unfavourable and required a reason ($X_{a,r}$). Here, r and $x_{a,r}$ are the respective sample data. The results are split between players that had no idea, or that gave an answer. In 14% of the cases, the player answered that they had no idea of the reason, which is a significant group. In the case of the other 86%, called r_f, another t-test was done. The total answered reasons are called $x_{a,r,f}$. Being very conservative, it is presumed that two of the four possible answers, were not well-formulated and nobody wanted to select these. The null hypothesis was that the players answered randomly, therefore: $H_0 : \mu_{R_f/X_{a,r,f}} = 0.5$ and $H_1 : \mu_{R_f/X_{a,r,f}} > 0.5$. Of the sample data, $\mu_{R_f/X_{a,r,f}}$ was 0.725, $\sigma_{R_f/X_{a,r,f}} = 0.356$. Therefore, p was 0.005365 and H_0 is rejected, so it is likely that H_1 is true for this 86% group of answers. Thus, players know the reason why some items have to be removed. However, from this data, it cannot be made certain that the knowledge of the reason was acquired by the game, although this is likely because players also significantly improved their (static) knowledge about the subject.

We presumed that quizzing the reasoning before playing the game would have a too big influence on the outcome. Further research with a control group and a higher n, should investigate the influence of the game on R. In that case, and by quizzing beforehand, attention might also be given to different subjects.

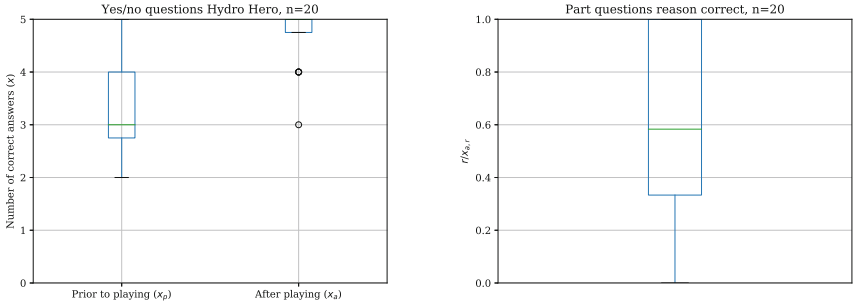


Fig. 6. Results of the quiz. Left: the number of correct answers given by players to the 5 closed questions, before and after playing the game. Right: percentage of correct justification answers (reasoning, only asked after the game).

6 Conclusion

We presented the serious game *Hydro Hero*, designed with the goal of reinforcing children's awareness for the challenges and responsibility of maintaining proper urban surface waters.

The validation data suggest that players of Hydro Hero increase their knowledge about canal cleaning and maintenance, though the exact extent of this increase has not been measured in this research. In addition, data also confirms that a majority of players significantly know why certain items are harmful in the domain of canal cleaning and maintenance; the influence of Hydro Hero in learning such reasons is probable, but has not been confirmed with certainty.

Besides the main research question, the time spent in the game by players proved that the game was moderately engaging, as intended. This helped in teaching the players, as they often mentioned they got the learning goal only after a number of rounds.

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