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Article

Playing for Keeps: Designing Serious Games for Climate Adaptation Planning Education With Young People

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Abstract
Citizen engagement around climate change remains a wicked problem. It is particularly challenging in relation to climate change adaptation at the local level. In response, this article presents the design steps taken to create a serious game for young people (aged 15–17) as a means to increase engagement in planning for climate change adaptation in Dublin. The iAdapt game acts as the capstone component of the audio and visual teaching and learning resources for adaptation education on the Climate Smart platform and uses open data, interactive in-browser 2.5D mapping and spatial analysis, and exemplar socio-technical adaptation interventions. Its primary aim is to empower young people to understand and engage with the complexities, uncertainties, and processes of climate adaptation planning by using scientifically validated flood data predictions, grounded in a place-based setting and with diverse examples of diverse adaptation interventions. Participants experience the difficulties of decision-making under conditions of democratic governance and uncertainty in order to educate, increase awareness, and stimulate discussions around the multiple possible pathways to planning for climate adaptation. Initial testing results with a cohort of young people in Dublin are presented. We conclude by reflecting upon the challenges of creating a game that has broad appeal yet remains enjoyable to play and the value of integrating real-world flood data with gamified elements. We also discuss the "value question" regarding the impact of games on expanding public engagement. Finally, the article sets out a plan for further development and dissemination of the platform and game.

Keywords
climate change adaptation; Dublin; education; flooding; iAdapt; serious games; youth

Issue
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1. Introduction

Both climate change and citizen engagement can be categorised as "wicked problems" (Rittel & Webber, 1973). That is, they are both arenas of action which are complex and lack a clear and fixed delineation of both aims and solutions. More than this, they are subject to real-world constraints that prevent multiple and risk-free attempts at their resolution. As dynamic, ongoing processes (e.g., in terms of climate changes and the nature of citizens' constituencies), it is unlikely that either will be permanently solved by a single response, with interventions needing to be relevant to the context in which they are applied. As contexts change so too will interventions need to evolve. In many cases, the way a wicked problem is described determines the range of potential solutions considered, flagging the importance of framing and bounding in shaping responses. Indeed, the wicked problems related to climate change and weak citizen engagement are themselves the symptoms of other challenges, from dominant and unsustainable production and consumption patterns to the structures of governance which dictate norms and practices of participation.

Attempting to engage people in climate change adaptation is then undoubtedly fraught with challenges. As already identified in the literature (McKinley et al., 2021), technology-led initiatives seeking to approach this issue often under-estimate the difficulties inherent in engaging people and communities. In the face of an ever-increasing likelihood of extreme climate events, these difficulties increase risks for already-vulnerable publics, particularly those who are marginalised or disenfranchised from policymaking. This is particularly challenging with regard to local level climate-change adaptation, where engagement is most needed and likely to be most effective (Hügel & Davies, 2020).

Despite the challenges and complexities, in this article, we face head-on the coincidence of these two arenas of wicked problems—climate change adaptation and citizen engagement—and present a novel approach to increasing engagement in strategic planning for climate change adaptation, based on the concept of "serious games" (Abt, 1970). Serious games aim to provide an entertaining mechanism for educating young people about climate change challenges whilst also engaging them in discussions about planning for climate change adaptation and the roles and responsibilities they might adopt to play a role in climate adaptation processes. In this endeavour, we built on the development of face-to-face, in-class workshops for young people located in an economically disadvantaged location of inner-city Dublin that is susceptible to flooding and predicted to experience increased numbers of, and more severe, flood events with climate change (see Davies & Hügel, 2021). We describe the process of converting these materials into online formats and outline the development of a serious game, iAdapt, which uses open data, interactive in-browser 2.5D mapping, and scientifically validated socio-technical interventions, to create a fictionalised future Dublin that the game players can shape through the selection of varied adaptation elements across multiple rounds (set as calendar years in the game) towards 2050. We explain the development of the testing protocol and reflect on early testing results, before outlining a suite of actions needed before wider dissemination of the approach in other locations.

2. Serious Games for Wicked Problems: A Review

As outlined above, issues related to climate change can readily be classified as wicked problems since, as Scannell and Gifford (2013) note, the global and long-term nature of climate change defies easy or immediate comprehension in our everyday lives. Indeed, the absence of a central authority to explore and implement solutions consistently and coherently within governments at all scales, while presenting policies that continue to discount future risks in the face of strong scientific evidence to do otherwise, and in spite of the increasing urgency to take action, have led to climate change being dubbed "super-wicked" by some (Levin et al., 2012). Allied to these factors is a lack of motivation to participate in climate change actions within communities that currently feel dislocated from climate change effects. As Spence et al. (2011, p. 46) point out in relation to climate change mitigation, "one of the reasons that people may not take action to mitigate climate change is that they lack first-hand experience of its potential consequences." Similarly, willingness to take adaptive action in relation to climate change is far more prevalent among people who have already experienced climate impacts such as flooding (Cone et al., 2013). However, despite this the need for public participation in responding to the problem of climate change is now well-established, having been included in Principle 10 of the Rio Declaration at the United Nations Conference on Environment and Development in 1992 and reiterated in the IPCC Special Report in 2018 (Masson-Delmotte et al., 2018). It is similarly well-established that mainstream methods of citizen engagement are not effective in driving inclusive participation in climate adaptation planning (Lane, 2005), especially in relation to marginalised and vulnerable populations and young people in particular. There are pragmatic and ethical justifications for enhancing participation and it is certainly a key requirement for any climate governance mechanism which intends to be perceived as legitimate (Alexander et al., 2018).

A recent literature review of public participation, engagement, and climate change adaptation (Hügel & Davies, 2020) identified three major themes that should be addressed to improve the status of citizen engagement in climate change adaptation: (a) the paradox of participation, (b) the challenge of governance transformation, and (c) the need to incorporate psycho-social and behavioural adaptation to climate change in policy processes. Specifically, it identified a need to enhance public participation in place-based, local adaptation policies and community practices that resonate with those whose engagement is sought. This area is a promising site for novel interventions such as educational games for young people where lessons learned in the classroom may serve as a "way in" to more comprehensive engagement efforts; that is, providing they are seen as relevant to and resonate with participants' lived experiences.

In this article, we focus on the concept of serious games as a potential motivator for engaging young people in climate change adaptation. Serious games, a term first proposed by Abt (1970), are games that are intended to inform, educate, and train players (Michael & Chen, 2005), though it should be noted that this does not mean that serious games cannot also be fun, merely that entertainment is not their sole or primary focus. The determining quality of a serious game is, instead, a "utility of purpose" (Girard et al., 2013, p. 4), and it must be designed with this in mind. Early examples such as *The New Alexandria Simulation: A Serious Game of State and Local*

Politics (Jansiewicz, 1973) were analogue in formation, taking their inspiration and mechanics from board games. Most current definitions are based on Sawyer's (2002) landmark research, which makes explicit reference to electronic games, although it should be noted that this definition has itself undergone considerable change over time (Djaouti et al., 2011). Serious games conceptually overlap with game-based learning (GBL), defined as the process of learning by using games (Becker, 2021), usually by re-using existing games that can be repurposed to achieve learning objectives. GBL is an instructor-led, supervised activity, which takes place in a learning environment such as a classroom (Dörner et al., 2016, p. vii). The key difference between serious games and GBL is that serious games are created expressly in order to fulfil the learning objective, and are thus custom-created, constituting the "core" of the activity, allowing them to be played in non-learning environments, without mediation by an instructor (though both are possible).

The increased sophistication and wide availability of electronic media and games in particular, which are now a large and growing feature of our cultural landscape, has further driven interest in online games for uses other than entertainment (Young et al., 2012). These uses fall into a number of overlapping categories: (a) persuasive games, designed as "rhetorical tools through which a designer can make arguments or influence players"; (b) games for change, designed as "critical tools in humanitarian and educational efforts"; and (c) serious games, whose primary aim is to "train or educate the player" (Coulton et al., 2014, p. 193).

Environmental education and policy have embraced the use of serious games, with Madani et al. (2017) identifying 25 examples in the area of environmental management alone. The majority of these (84%) are aimed at a combination of students, professionals, and stakeholders (Madani et al., 2017), with students often being the primary audience, with no distinction made between those in primary, secondary, or tertiary education. Management and role-playing games are the most common format in this category (Reckien & Eisenack, 2013). Climate change education, too, has embraced the use of serious games in a number of areas including water management (Valkering et al., 2013; Villamor & Badmos, 2016), climate negotiations (Sterman et al., 2015), and in terms of understanding risk (Parker et al., 2016).

In their review of online and analogue (e.g., boardgame) climate change games from 1983 to 2013, Reckien and Eisenack (2013) found an even split between a focus on global and local sites of action, with a smaller focus on Europe compared to the rest of the world, noting that most games used English as the game language, with a primary focus on mitigation (86%) as opposed to adaptation (40%). Wu and Lee (2015) have observed several emerging trends in games as tools for climate education and management in their more recent review, including a trend towards mobile games, a move from "virtual'' or computer-based spaces to augmented or real-world physical spaces, and the incorporation of real-world interactions.

More recent work indicates a shift towards a more even split between mitigation- and adaptation-focused games. In their analysis of two role-playing simulation games for adaptation, Rumore et al. (2016, p. 2) found that these were effective in "cultivating climate change adaptation literacy, and enhancing collaborative capacity." A more wide-ranging review (Flood et al., 2018) confirms this increasing attention to adaptation as well as a shift towards the local scale and approaches such as social learning to address the adaptation deficit which arises as a result of insufficient knowledge (Edwards et al., 2019). Their review of the effectiveness of the interventions found that high levels of trust are required between researchers and participants, coupled with robust evaluation methodologies. Finally, a review that used a 15-attribute climate change engagement framework to analyse the content of serious games found that while most of the surveyed serious games (n = 109) were feedback-oriented—attempting to strike a balance between challenge and skill and incorporating elements of experiential learning—social play was a rare feature of the game corpus (Galeote & Hamari, 2021).

It is clear from the more recent reviews that serious games continue to be a popular tool for education and engagement, but, despite a long period of growing research interest, some areas remain under-explored. While there is some evidence of a shift, as described above, most climate change games still predominantly focus on mitigation. This may be because mitigation actions are more easily explained and lend themselves more readily to the mechanics of gameplay, whereas adaptation actions are multi-faceted, often include a policy focus that can be less tangible, and are carried out under conditions of uncertainty. While understandable, it is important that games do not oversimplify or otherwise disguise the complexity of the "real" world (Parker et al., 2016) given this is a central feature of adapting to climate change. Nonetheless, it is acknowledged that integrating validated physical science, socio-economic and policy impacts of climate change, and adaptation actions, in ways that are plausible and readily understood by non-expert audiences and young people in particular, while also ensuring that a game is fun to play represents a considerable design challenge.

Recognising the challenge between realism and entertainment in the context of climate change adaptation leads to another acknowledged difficulty of serious games: definition and assessment of success criteria. There is a need to measure the impact of the game on broader learning activity, which includes how the game impacts the players' knowledge, their interest in the subject, and capacity to act, as well as their willingness to engage in activities beyond the game itself. However, it is always difficult to identify a direct cause-effect relationship between playing a game and impacting a sense of efficacy, which is undoubtedly affected by many other variables outside the serious game engagement itself.

Wider socio-technical issues also remain underexplored; given that most definitions of serious games assume an electronic medium and publications often describe the technical components of the game in considerable detail (e.g., Neset et al., 2020), none of the surveyed literature reflects upon the impact of the technical choices (such as the chosen platform, medium, or use of particular visualisation technologies) on the games' audiences, the ability to scale the game, the availability of their components for re-use, remixing or other forms of adaptation, and their longevity.

In the remainder of this article, we address these limitations in the existing literature, setting out the design approach for a serious game element (iAdapt) of an integrated learning platform, Climate Smart.

3. Climate Smart Design Approach

The iAdapt serious game is the capstone element of an educational module designed for transition-year students (aged 15–17) in Ireland. The original intent was for the module to be taught in person in the classroom, and a pilot was developed and operationalised (Davies & Hügel, 2021). However, the impact of Covid-19 in 2020 made further testing and development impossible, and the decision was taken to design an online platform—called Climate Smart—to deliver the workshop content, with the game being "unlocked" upon completion of the module components. To this end, a custom web platform was developed to host and distribute the content. The platform allows users to register as individuals, students, or teachers and is designed to capture and retain the minimum amount of data about the user's activity on the site while capturing as much anonymised gameplay data as possible. A name and email address are required to register, but neither is verified. If a user is registering as a pupil, they must enter a pre-supplied enrolment code which allows their teacher to view their workshop progress, but no other site activity data such as times or dates of interaction.

The educational module is divided into five workshops (Table 1). Each workshop is broken up into sections of approximately five minutes, consisting of video and animation, followed by a multiple-choice quiz which must be completed in order to move on. Progress through the workshop sections is recorded, with the most recent uncompleted section automatically being shown to the participant upon login, and an overview of completed and uncompleted sections being available. The game becomes available once all the workshops have been completed. The platform also hosts the geospatial data—modelled pluvial and fluvial flood extents and the location and outlines of the interventions—required for the iAdapt game, which is played in a web browser.

A design approach was adopted based on an informant design framework that involves stakeholders at different stages of the design process depending on their expertise in order to maximise the value of their contributions (see Figure 1).

Table 1. Breakdown of workshop content.

Workshop Name	Workshop Content
1. Introduction to climate change	1. Introduction to climate change as a concept 2. Defining adaptation and mitigation 3. Introduction to climate science 4. Global climate policy context 5. Irish climate policy context
2. Flooding in Ringsend	1. Introduction to flooding 2. History of flooding in Ringsend 3. Defending against flooding 4. Defending against coastal flooding 5. Planning and building flood defences
3. Future floods	1. Introduction to flood monitoring 2. Using flood data 3. Flood modelling and uncertainty
4. Sensing floods	1. Visualising flood impacts 2. Flood impacts in Ireland 3. Floods and feelings 4. Taking flood action 5. Irish flood management practice
5. Adapting to our changing climate	1. Grey infrastructure interventions 2. Nature-based interventions 3. Policy and behavioural adaptation

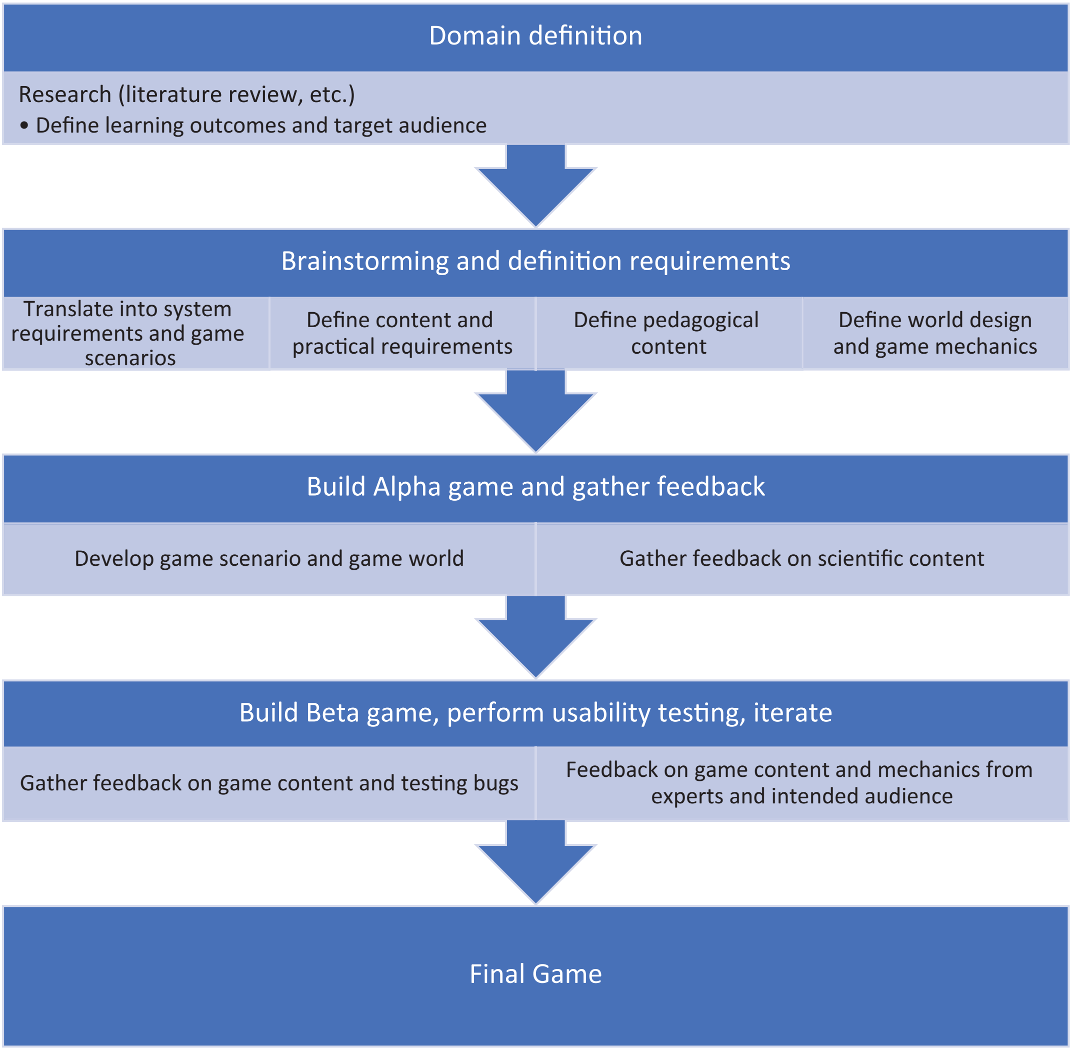

Figure 1. Design methodology framework. Source: Authors' work adapted from De Jans et al. (2017).

Learning outcomes were identified as: increasing knowledge about predicted climate change impacts in Dublin and the complex processes of planning for climate change adaptation; increasing understanding of the pros and cons of different options for climate change adaptation; improving players' confidence about participating in climate change adaptation planning processes; and increasing understanding amongst players that there is not a single perfect solution to the problem of climate adaptation—measures must be evaluated and balanced against their respective advantages and disadvantages. Initial world design and mechanics were sketched out and discussed using an interactive storyboarding tool (Arnold et al., 2013) before alpha and beta versions of the game were produced by researchers (the authors of this article) with skills in digital development, citizen engagement, environmental planning, and climate change. Virtual workshops on the beta version were held with climate scientists, policymakers, serious game designers, and teachers to provide expert feedback on the game design and its components. The game is a turn-based role-playing game that is intended to simulate the process of decision-making under conditions of uncertainty in the context of climate adaptation planning. While it is intended to be played following the completion of the workshops, complementing these, and drawing together their themes and materials in an exercise that is intended to be both fun and instructive, the game design also provides help functions with explanations of key terms for any player who has not completed the associated modules.

The player's character is the newly elected mayor of Dublin, in the year 2045. Players choose an avatar from a variety of ethnicities and genders intended to reflect a broad range of the Irish population. While the role of the mayor of Dublin is currently not invested with any powers to direct flood defence in the city, this decision was made in order to strengthen the narrative cohesion of the game; it is simpler to play as a powerful figurehead than a committee of planners, scientists, and civil engineers.

The game is round-based, with each round representing a year. Each round is broken down into four phases, reflecting core dimensions of commonplace "real world" planning processes: planning, consulting, revising, and adoption.

3.1. Planning

During the "plan" phase in each round, interventions can be bought and sold according to a fixed and limited budget (see Figure 2). These interventions fall into one of the following categories: Grey, Mixed, Green and Blue, and Policy. These interventions are drawn from a variety of sources: interviews with experts in flood adaptation, public participation, and climate science; a review of the scientific literature on flood defence infrastructure and civic society approaches to increasing participation in climate adaptation planning; and data from Ireland's Office of Public Works.

Interventions are priced according to their scale and complexity, not according to present-day costs, with some large physical and societal interventions taking multiple rounds ("years" in the game) to complete and begin to provide benefits. Interventions display a brief description, advantages and disadvantages, and the type of flood event they protect against. Each intervention is also assigned a hidden measure of popularity with each of four political affiliations allocated to Dublin's population at the beginning of each new game: right, centre, left, and green voters. An intervention can defend against a certain amount and type of flooding or increase societal resilience by some amount. As interventions are purchased, they are displayed on an interactive 2.5D map of Dublin, coloured according to their flood protection type. The player is automatically "flown" to the site of the intervention when it is selected, and it fades into view when it is purchased.

The interactive map is the main feature of the game. Previous research (Davies & Hügel, 2021) has shown that the intended audience found the use of such interactive maps enjoyable, useful, and compelling, and this finding was used as the basis for the map's design, which allows smooth zooming, panning, and tilting to present either bird's-eye views of the city or highly detailed views of a far smaller area. The map also features environmental and atmospheric effects such as fog and changing sky colour according to the time of day: A game played early in the morning will be differently illuminated than one played after sunset.

3.2. Consulting

During the consultation phase, the public reacts to the player's plan. The reaction can be positive or negative, according to the total score of each purchased intervention multiplied by the proportion of each political affiliation that was allocated to the population for the game. For example, the construction of a sea wall might be popular with centre- and right-wing voters as it protects property in an affluent area, but it might be unpopular with left and green voters as it is an expensive

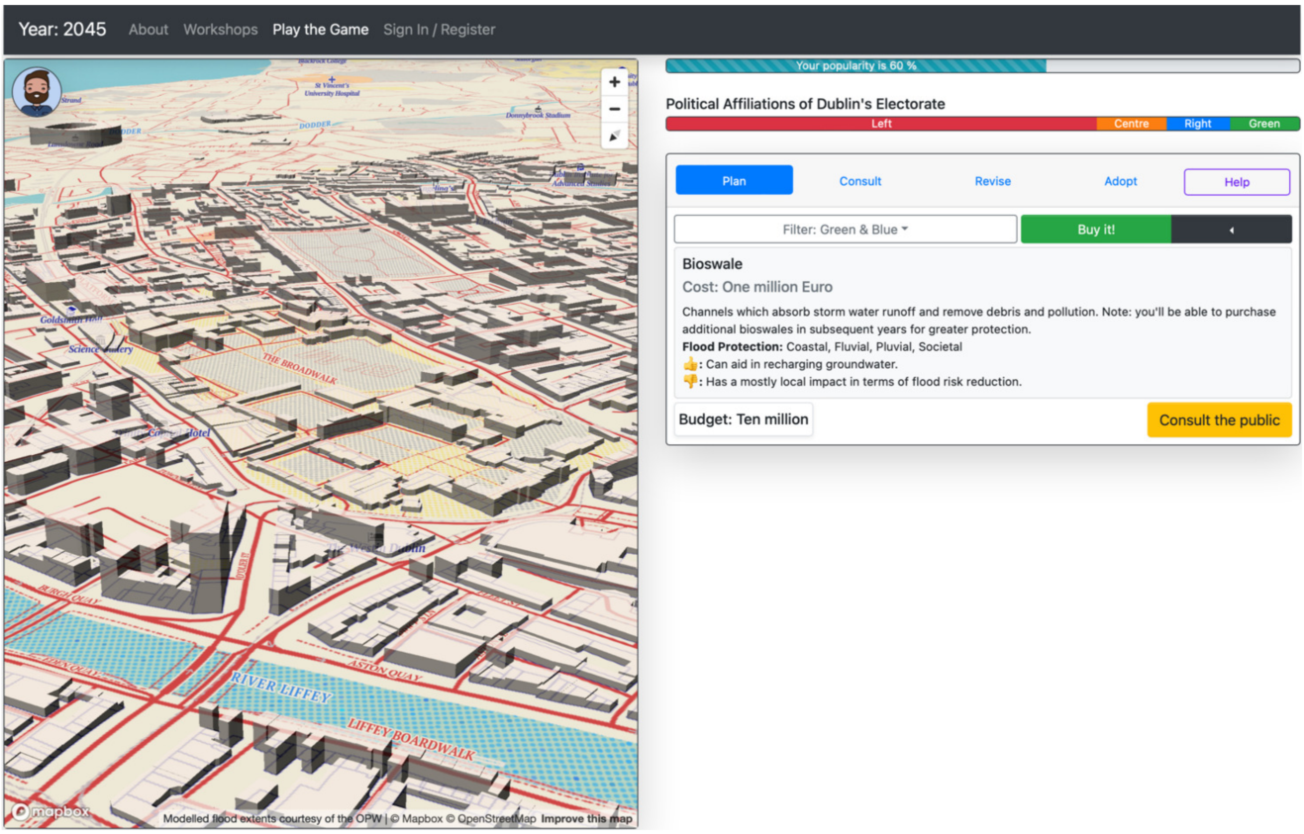

Figure 2. Gameplay showing information about the selected intervention.

carbon-intensive project which benefits a relatively small proportion of the city's population. Thus, in a game with a large proportion of green and left-wing voters, deciding to purchase this intervention is politically costly and can lead to the game ending early if the player's popularity drops below a certain level. This possibility is foreshadowed by the triggering of a protest action if public opinion on a proposed plan is below a certain threshold: A large protest crowd is simulated in one of several central areas of the city (see Figure 3), coupled with audio samples of actual protests.

Players also receive "expert feedback" on each proposed intervention during the consultation phase from one of three experts: the country's chief economist, the government's chief scientific officer, and a prominent social think-tank CEO. This feature has two purposes: first, to add additional factual context drawn from the literature concerning each intervention, and, secondly, to allow the player to decide whether the intervention "fits" with their chosen style of play.

3.3. Revision

The third phase—"revision"—is the same as the planning phase in terms of functionality; interventions bought in the planning phase may be sold and others bought based on feedback from public and experts. If the plan *is* revised during this phase, it will be re-evaluated by the electorate, which can lead to a rise or drop in popularity.

3.4. Adoption

During the final phase—"adopt"—the plan is activated and a flood event occurs (see Figure 4), and its impact on Dublin is measured and represented on the interactive map. During this phase, sounds of crashing waves are played, and the player is slowly "flown" around the extent of the flooded areas. These effects are intended to convey the scale and impact of modelled future flood events. In order to visually convey the distribution of flood adaptation actions, the centroids—the centre of mass of a built intervention or the building in which it takes place—of all purchased interventions are calculated and used to form a triangulated irregular network, which is overlaid on the flood extents which are displayed on the map. These extents are based on scientifically modelled fluvial and coastal flood extents for the city of Dublin in the year 2050 (Environmental Protection Agency, 2019). Flood events can occur in one of three randomly chosen magnitudes—low, medium, and severe—and one of three types—fluvial, pluvial, and coastal. A low-magnitude event involves one flood type, a medium-magnitude event involves two (randomly chosen), and a severe flood event involves all three types.

The player is shown the amount of damage incurred and defended against, as well as the level of societal resilience they have built up. Before advancing to the next round, the player is given advice about how effective (if at all) their defences are against the various flood

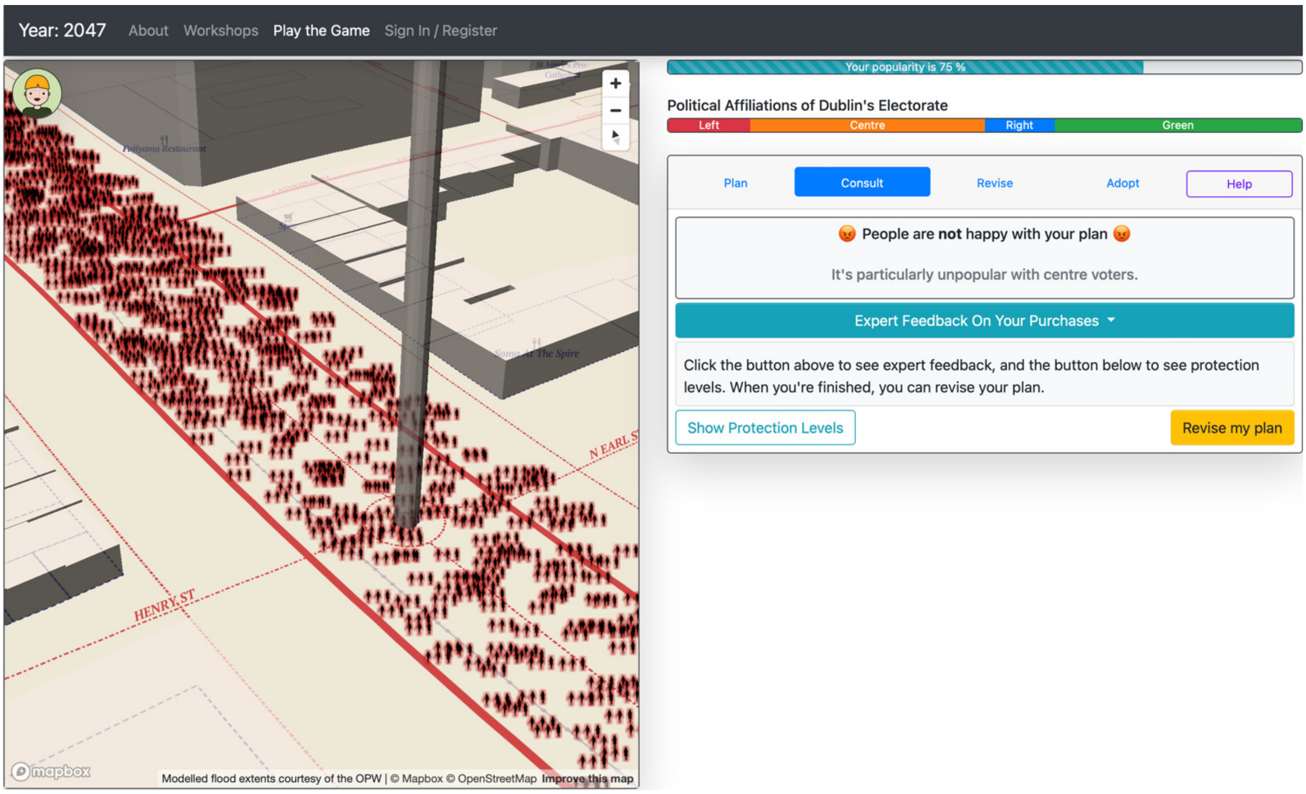

Figure 3. A protest action.

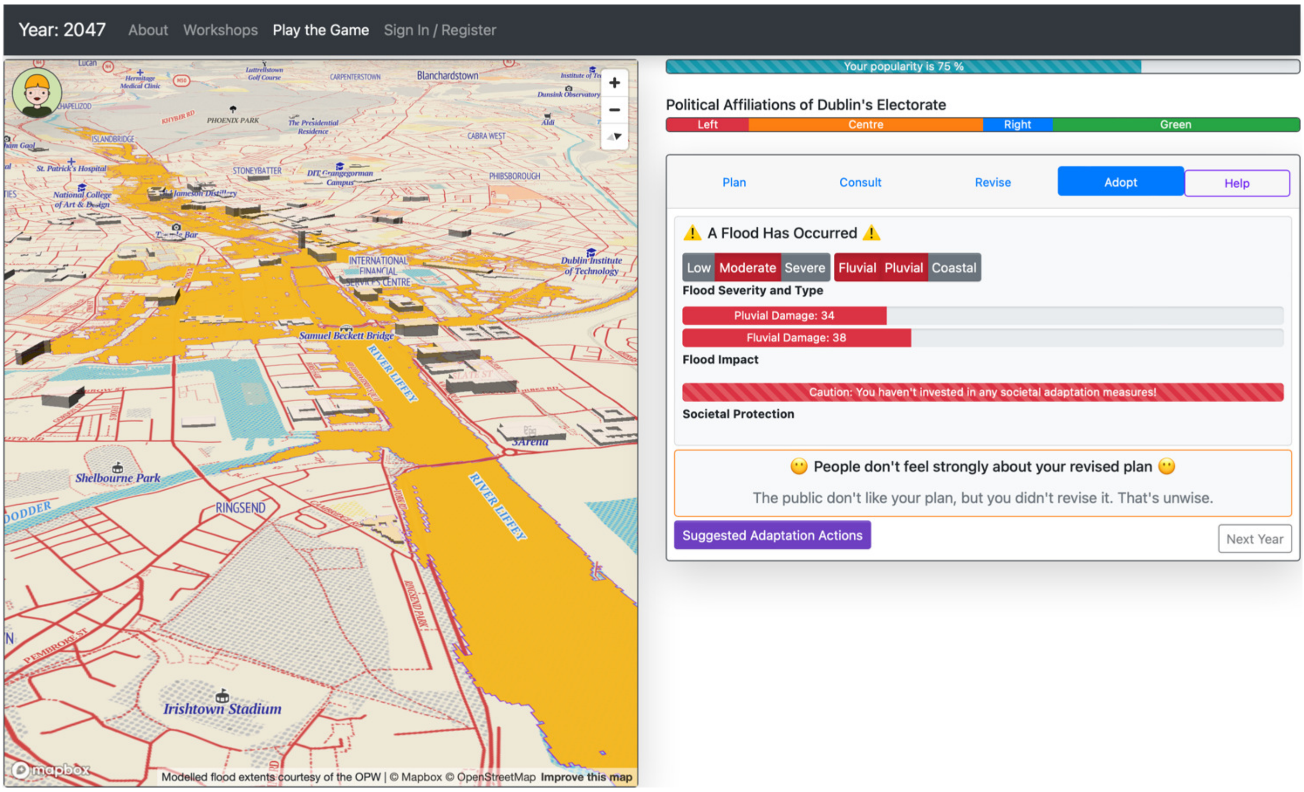

Figure 4. A moderate flood event, showing modelled fluvial flood extents (in orange) for the river Liffey.

types and magnitudes. In addition, the protection levels of all green and blue infrastructures are increased by 10% in order to "nudge" players towards their use. The plan, consult, revise, and adopt cycle is then repeated five times towards the end year of 2050.

3.5. End Game

The game ends in one of two ways: the year 2050 is reached, or the player's popularity drops below 20%. The player is then taken to an "endgame" screen, where their score is shown. The score is calculated by combining three factors: the total percentage of flooding defended against by purchasing physical interventions, an additional bonus set at 100% of the proportion of the total budget that was spent on green and blue interventions, and 50% of the proportion of the total budget that was spent on mixed interventions. The latter two bonuses are applied as green and blue (and some mixed) interventions are considered to have co-benefits such as "water savings…air quality improvement and carbon sequestration" (Alves et al., 2019, p. 244). This score is ranked against all previous game scores and the player's position is displayed relative to the scores of other players.

The end screen also shows a variety of graphs relating to the game:

1. The magnitude of flood defences the player has built up during the game, broken down by type;
2. The player's popularity amongst the public across the game;
3. The type and severity of the flood event that occurred each year;
4. The amount of flood damage that occurred following the annual flood event, broken down by type;
5. The breakdown of spending on each defence type across the game.

This detailed breakdown (see Figure 5) is designed to facilitate in-class discussion of the results by the teacher by showing the links between flood defence levels, severity, and damage, as well as indicating public opinion.

Once the prototype game was operational, testing could begin.

3.6. Testing Methodology

A usability testing protocol for the game was developed based on the frameworks proposed by Lowry et al. (2013) and Olsen et al. (2011). Olsen et al's framework stipulates three focus areas: usability, playability, and learnability/educational merit. Usability focuses on the independent functionalities within individual components of a system. Playability, on the other hand, focuses on a broader sense of overall functionality associated with the integration of several usable tools, allowing for successful, satisfying, and, importantly, enjoyable interaction with a game (Olsen et al., 2011). As a holistic experience, playability is a key trait of serious games. However, there are no agreed-upon and widely used measures for it. There are however associated measures that share similar components to those that are of

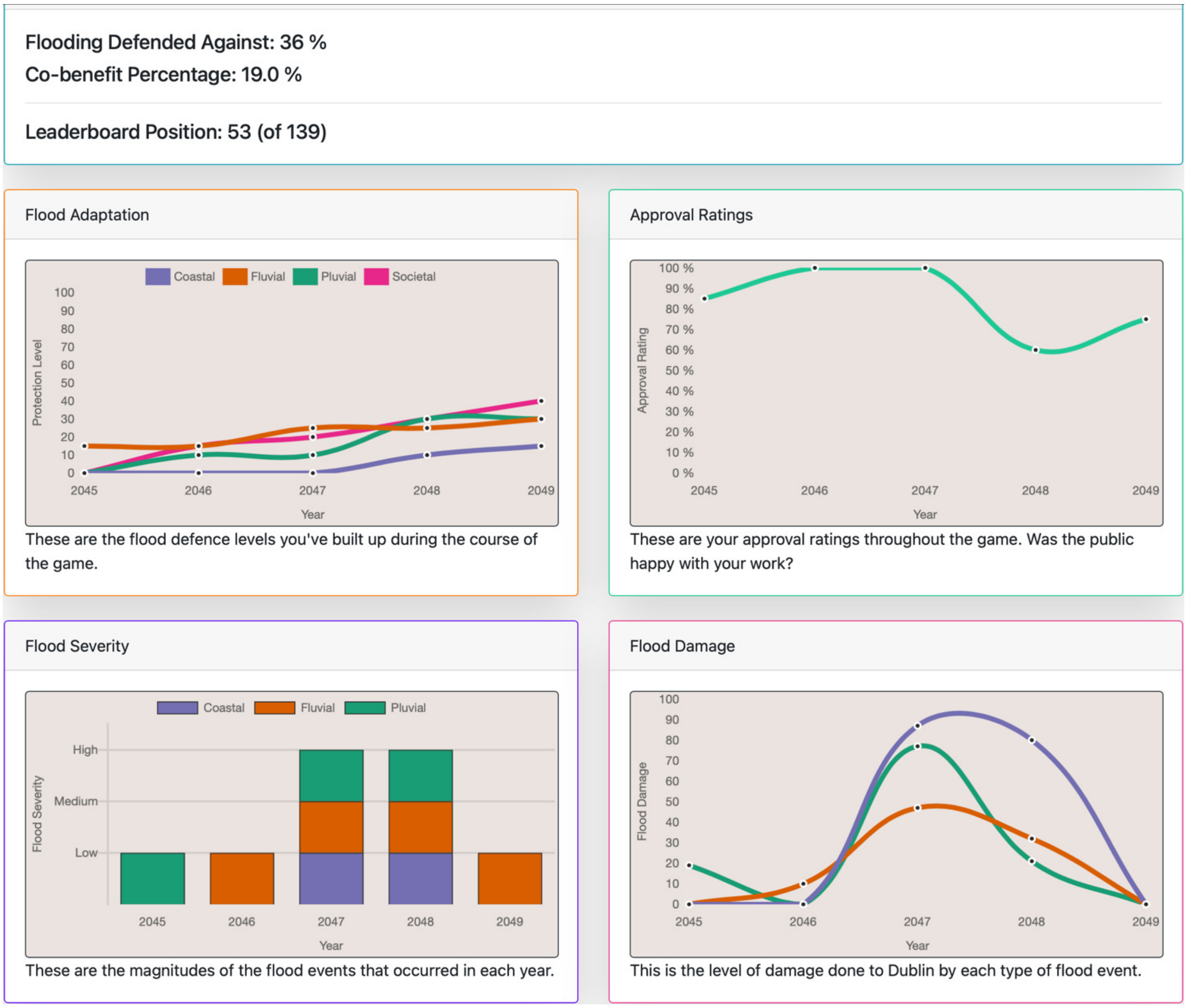

Figure 5. End game screen with gameplay statistics.

interest in serious game usability testing; these include scales of immersion and presence (Witmer & Singer, 1998) and engagement (Brockmyer et al., 2009). By contrast, Lowry et al.'s hedonic-motivation system adoption model (HMSAM) is designed to improve the understanding of hedonic motivation systems (such as games) by attempting to understand flow-based cognitive absorption (Jackson & Eklund, 2004). In addition, it was essential that progress towards the desired learning outcomes was captured during the testing phases of the game to ensure that the game achieves its primary objectives. Focusing too much attention on the "fun" aspects of a game can result in the sacrifice of learning effectiveness. Poor usability can also impair learning by taxing cognitive resources and decreasing motivation to play the game. Therefore, assessing learning outcomes at various stages during development can help determine possible causes of increases and decreases in learning. A suite of questions (Table 2) was developed in order to measure each of these dimensions.

4. Testing Results and Discussion

Testing took place with a cohort of 20 transition year students studying at an inner-city Dublin school which is designated as a DEIS (delivering equality of opportunity in schools) school. Transition year students from this school had participated in the face-to-face version of the workshop (Davies & Hügel, 2021) although the game testing group was a different cohort. Testing was conducted face-to-face within the classroom over a period of two classes (approximately 1h20m) with students as individual players engaging in a period of free play, before facilitators played through the game with the students, phase by phase, with detailed pre-set questions related to each phase being asked. Students were able to raise their own issues throughout the process.

Key results of testing are discussed in this section around (a) supports and understanding, and (b) motivations for actions in their gameplay. This is done for ease of comprehension in the article, although these

Table 2. Usability questions asked during playtesting.

Game Section	Question	Usability Component	HMSAM Component
Start Page/ Mayor Selection	Who read the instructions?	Learnability	Perceived ease of use
	If you read them, did you understand them?	Learnability	Perceived ease of use
	What was *unclear* about the instructions?	Learnability	Perceived ease of use
	Why did you choose the mayor you used to play the game?	Playability	Game-specific self-efficacy
	Is there anyone else you would want to see represented as a mayoral candidate?	Satisfaction	Behavioural intention to use
Gameplay	Did you know where the help button was, and did you think anything was missing from the help text?	Learnability	Perceived ease of use
	Did you find it easy to find and select things to buy using the dropdown menus?	Memorability	Perceived ease of use
	There are four categories for the things you can buy: policy, mixed, green-blue, and grey. Do they make sense to you?	Memorability	Perceived usefulness
	Did you know you can click something you bought to sell it again?	Playability	Perceived ease of use
	Did you understand that the things you buy affect your popularity?	Playability	Perceived usefulness
	Did you understand what the "consult" phase was for?	Learnability	Perceived ease of use
	Did you understand what the "protection levels" button does?	Learnability	Perceived usefulness
	How many people used the revision phase to change their minds about what they'd bought?	Playability	Perceived usefulness
	Did you understand the different flood levels?	Learnability	Game-specific self-efficacy
	Did you understand that the things you bought reduced the flood impact?	Learnability	Game-specific self-efficacy
	Was the suggested advice useful? Did it help you plan what to do in the next round?	Playability	Game-specific self-efficacy
	You don't have to spend the entire budget per round, but the remainder doesn't carry over from one round to the next—What do you think of this feature?	Efficiency	Perceived usefulness
	Was it easy to follow the game as you followed through the phases and rounds?	Playability	Perceived ease of use
Results Screen	Who looked at the results graphs at the end of the game? Did you understand what they represented?	Playability	Perceived usefulness
	Did the end-game screen give you a good sense of how well you did in the game and motivate you to play again in order to improve your score?	Satisfaction	Perceived usefulness

two categories clearly influence each other: For example, supports can motivate players to engage with the game across its duration, and motivated players are likely to make the most use of the supports provided.

4.1. Supports and Understanding

Most students (70%) read the introductory instructions; however, some felt that these were too long, with some confusing elements. No students watched the introductory video that is embedded on the landing page of the game. This is problematic as while it is possible to play the game intuitively, with participants finding their way through the game by trial and error, it is important that the mechanics of the game are clear and the goals transparent if learning outcomes are to be optimised, as "explicit learning tasks, instructions, and support" (Iten & Petko, 2016, p. 1) may be more decisive factors in the achievement of learning goals than the experience of fun.

The next set of questions focused on the help system. Students reported that they either did not realise that there was a help function available or did not make use of it if they did. This was an interesting finding, as the ability to know how to achieve the game's objective is a core concern, however, it is evident that the present help system needs revision; some level of assistance is useful and motivating, but it is clear that players cannot be expected to seek out help if it is not immediately obvious to them. Instead, it may be more effective to provide unprompted contextual "scaffolding" (Obikwelu et al., 2012) as part of the gameplay, based on heuristics such as player popularity, balance of purchases between categories, and total amount of flooding defended against, perhaps at the halfway point in a game.

The difference in flooding levels experienced during the adoption phase was understood by most students, as was the need to purchase a variety of interventions to defend against flooding. This was an encouraging finding, as this is the core mechanic of the game: If players do not understand the objectives and how to achieve them, they cannot effectively play the game, and the learning outcomes cannot be met. Only one student admitted to finding the game confusing, and it was clear from students' answers that they understood the mechanics and objectives. However, as with the help button, most students did not read the advice given to them concerning protection levels at the end of each round, and responses to questions about contextual audio cues such as crashing waves were mixed. Some students reported that they would prefer no sound, however, others requested optional soothing music, as the game required concentration. While personal preference is clearly a factor this feedback suggests more attention to the use and impact of sensory cues, such as sound, is required as existing literature has not taken this issue to task.

Regarding the end game section, most students found the prominent display of their leaderboard position motivating, and said it would encourage them to play again, and some wanted to see their scores in relation to their classmates' scores. This supports Lee et al.'s (2019) research which demonstrates the value of competition in achieving learning goals. There was a range of opinions concerning the graphs: some found them confusing, while others understood the relationship between the graphs and their in-game actions and choices. Approximately 50% of participants understood that there were different types of flooding and that these had to be separately defended against. Of the 20 participants, 19 said they would want to engage in another gameplay session, which is a positive outcome of testing.

4.2. Game Play

Reported motivations for the students' choice of mayor varied: Some chose a character that matched their gender, others chose based on the stated mayoral attitudes towards Dublin ("I chose him because he said 'Dublin is a modern city.'"), and students were broadly happy with the variety of choices that were available to them, though some requested that locally known community figures could be incorporated. A surprising finding at odds with the literature (see, e.g., Lakhmani & Bowers, 2011; Oksanen et al., 2013) was the negative reaction towards a proposed feature which would allow players to design their own mayor: During the brainstorming phase, several student respondents (see Figure 1) noted that this functionality is common and may contribute to players being more invested in doing well, but during testing, participants noted that this would distract players from focusing on the game objectives.

Discussions about choosing interventions revealed a range of responses from the students: Some chose interventions completely at random yet managed to score quite highly; others chose the interventions they thought sounded "the best" in terms of adaptation benefits. However further testing is required in order to ascertain precisely how students ranked interventions. Some students were puzzled by the terminology describing the interventions, some did not realise that items could be bought and sold again during the planning phase, and there was a degree of confusion about the differences between some of the categories: While the difference between the "grey" category and others was clear, some students felt that the "green and blue" and "mixed" categories were essentially the same despite guidance differentiating between these categories.

The relatively high threshold for triggering protests against plans meant that students did not generally consider the popularity of interventions amongst Dublin's population when purchasing. Further engagement with popularity and with the details of interventions could have emerged during further gameplay (Ravyse et al., 2017); however, due to time constraints, the testing did not allow for further autonomous play. Additional testing with this cohort and others is required to verify whether repeated play has an impact on engagement with these elements of the game to maximise learning outcomes.

Approximately 50% of students did not spend their entire budget every year, and most did not use the revision phase to change their plans. This was likely related to the fact that the threshold for receiving negative feedback in the form of protest actions is set too high. However, it might be a reflection of a lack of engagement with the advice given on the nature of interventions and their impacts, including their costs (financial and otherwise) and benefits. It could also be a result of a desire to progress through the game quickly, rather than spend time identifying an intervention that they could afford with their remaining budget, which requires time to go through the drop-down menus and identify interventions that were available to them. While the literature is relatively silent on optimum length of play, this needs to be explored with more testing to ensure optimum engagement whether during free individual play or playing as part of a classroom exercise.

4.3. Next Steps

This article focuses on initial testing with the target audience of transition year students in a DEIS school. An important next step involves wider testing and validation of the game approach, repeating the workshop with the same cohort for more in-depth feedback as well as testing with other student cohorts and with educators. The place-based nature of the game—currently in the Dublin city region—is key to activating engagement (Scannell & Gifford, 2013). The level of effort required to translate the game to other settings also needs to be explored. Providing suitable maps and flood data are available for other settings in Ireland and internationally it could be relatively straightforward to replicate the game process in other settings. Further work is required in order to modify the platform to allow the modular substitution of interventions and flood data, and specific pre-game workshop materials would also need to be adapted to local settings.

5. Conclusion

The process of creating a serious game for increasing engagement with climate change adaptation was complex; there are multiple drivers for the game, and these may not always point in complementary directions. For example, the game has to be appealing to the target audience (and ideally beyond that grouping) in all its diversity (e.g., employing an intersectional reading of societal groups) to encourage engagement, but it must also have some "real world" complexity that underpins the challenge of planning for climate change adaptation if learning outcomes are to be achieved. Predictions are dynamic and will need to be updated as science moves forward with increasing specificity and, one hopes, accuracy around mapping out potential flood futures for the region. Additionally, the so-called "value" question remains, that is, ascertaining the efficacy of serious games for (a) supporting increased awareness of processes, policies, and potential responses; (b) supporting increased understanding of the nature and complexity of "wicked problems" such as climate change; and (c) supporting players to actively engage with processes of adaptation planning post-game play. Test results to date suggest that Climate Smart has positively supported increased awareness (a) and, linked to that, some signs indicate a greater understanding of the process (b), although this needs to be tested with and without the online workshops to ascertain relative impacts of both approaches. However, it is hard to follow the participants to see whether engaging with the game stimulated the active engagement with adaptation planning in the absence of longitudinal studies. Distilling direct cause-effect relations in the messy world of lived realities does however make drawing definitive conclusions hard to ascertain. Nevertheless, at this preliminary stage, lessons learnt from testing suggest that the use of place-based interventions, situated in an area with which players are familiar does seem to increase players' enjoyment of the game, and thus willingness to play. The degree to which this is the case—and whether this would decrease if an unfamiliar or even fictional city were used as the basis for the game—demands further exploration, as does the resource input required to modify the Dublin-focused iAdapt game to focus on other contexts.

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Conflict of Interests

The authors declare no conflict of interests.

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