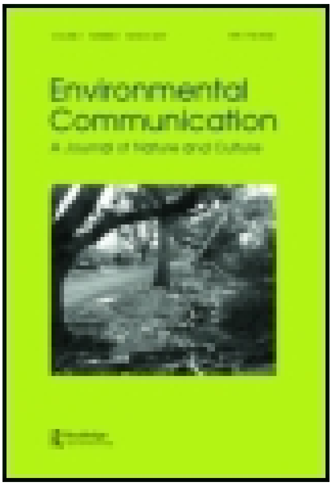

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Visual Climate Change Communication: From Iconography to Locally Framed 3D Visualization

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Climate change is an urgent problem with implications registered not only globally, but also on national and local scales. It is a particularly challenging case of environmental communication because its main cause, greenhouse gas emissions, is invisible. The predominant approach of making climate change visible is the use of iconic, often affective, imagery. Literature on the iconography of climate change shows that global iconic motifs, such as polar bears, have contributed to a public perception of the problem as spatially and temporally remote. This paper proposes an alternative approach to global climate change icons by focusing on recognizable representations of local impacts within an interactive game environment. This approach was implemented and tested in a research project based on the municipality of Delta, British Columbia. A major outcome of the research is Future Delta, an interactive educational game featuring 3D visualizations and simulation tools for climate change adaptation and mitigation future scenarios. The empirical evaluation is based on quantitative pre/post-game play questionnaires with 18 students and 10 qualitative expert interviews. The findings support the assumption that interactive 3D imagery is effective in communicating climate change. The quantitative post-questionnaires particularly highlight a shift in support of more local responsibility.

Keywords: *visual communication; images; attitudes; climate change; landscape change; educational games*

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Introduction

Climate change is an urgent problem with implications registered not only globally, but also on national and local scales (IPCC, 2007). It is also a "wicked problem" that seems too abstract to many people (Cohen, Demeritt, Robinson, & Rothman, 1998). It was the purpose of our study to overcome these barriers by developing and testing interactive visualizations of local climate change impacts and actions that can be implemented to highlight the connections between cause and effect, i.e., to localize, visualize, and connect (Sheppard, 2012). In this paper we analyze the effective use of interactive images within the virtual environment of *Future Delta*, a time-forward 3D visualization and simulation educational game that aims to foster communication, motivate action, and promote behavior change among its players (Dulic, Schroth, Shirley, & Sheppard, 2011). *Future Delta* localized the impacts of climate change by situating the imagery of the game in a recognizable neighborhood of the flood-prone municipality of Delta, BC, Canada. In addition, future scenarios were based on identifiable impacts related to the Delta area, with consequences that could inform local communities. *Future Delta* visualized climate change by combining climate change modeling, socioeconomic scenario analysis and 3D modeling of real places with engaging soundscapes and imagery. These multimedia images and interactive tools tried to make climate change science and solutions more salient and understandable to the layperson (Nicholson-Cole, 2005; Slovic, Finucane, Peters, & MacGregor, 2002). Finally, *Future Delta* connected communities through experiential learning in an interactive virtual environment. Through engagement in the game environment, different constituents had access to climate science, adaptation, and mitigation solutions, locally relevant 3D images and future scenarios. Building on the local climate change visioning project, led by Stephen Sheppard at the Collaborative for Landscape Planning, the 3D game was designed and tested in Kelowna at the Centre of Cultural and Technology under the direction of Aleksandra Dulic.

The aim of the evaluation of the *Future Delta* prototype[1] was threefold: first, to analyze the effectiveness of interactive 3D imagery and multimedia for communicating and motivating action on climate change; second, to evaluate player interaction and game play for further game design and refinement; third, to test the best practices for evaluating game environments for educational purposes. The follow-up study of *Future Delta 2.0*, scheduled for 2013–2017 will build on, adjust and refine the study parameters established in the first round of testing with a much larger sample. In this paper we primarily focus on the first objective of this study: Is interactive 3D imagery within a game environment effective in increasing the perceived understanding of local climate change issues and actions? Does playing a climate change game in a virtual environment increase a sense of local and individual responsibility? Can 3D imagery and virtual gaming contribute to a change in attitude and behavior?

Building on Leiserowitz (2006), this paper refers to 3D imagery as time based, animated, and computer-generated simulations of audio-visual representations in an interactive game environment. Future Delta used an interactive 3D game environment that visualizes local climate change challenges and solutions as a means to increase awareness and motivate support for policies on adaptation and mitigation strategies.

Making the Invisible Visible: Communicating Climate Change through Interactive Images

Today, there is consensus within the scientific community about the anthropogenic causes of climate change, its severe consequences and the need for mitigation and adaptation actions. Nevertheless, climate change action remains a low priority in the public perception. Hulme (2009) takes a closer look at the question of why we disagree about climate change and comes to the conclusion that we receive multiple and conflicting messages about climate change which are also interpreted in different ways. Hulme presents alternative communication models, specifically rejecting the traditional "deficit model," where scientists inform the public through seemingly neutral media in a one-way communication process. Other scholars suggest that climate change communication needs a model based on dialogue, such as the idea of "circuits" proposed by Carvalho and Burgess (2005). In these circuits, it is understood that no message is neutral but different social actors such as scientists, media, and the public always *frame* climate change differently according to their ideological worldview and emphasize certain aspects of climate change while de-emphasizing others (Hulme, 2009; Olausson, 2011).

Three-dimension images and interactive environments can also be analyzed in the context of communication for social change, where interactive representations create emergent meaning and reflect locally relevant, culturally meaningful icons (Dulic & Hamel, 2008). These multimedia representations extend the range of climate change images, creating a complex visual rhetoric that reflects the specificity of locally framed climate change issues. This supplements a limited palette of iconic images that are expected to be meaningful to diverse communities with diverse climate challenges.

Why people are not concerned about climate change

Moser emphasizes the specific challenges and barriers that distinguish effective climate change communication from environmental communication in general: (1) the cause of climate change, greenhouse gas emissions, is mainly invisible, (2) at least in the Western world, most people perceive the impacts as temporally and geographically distant, (3) modern society has been insulated from its physical environment in general and people lack exposure and sensitivity to climatic extremes, (4) if mitigation action is taken, the benefits are difficult to see and gratification will only benefit future generations, (5) according to a survey described by Leiserowitz, Maibach, and Roser-Renouf (2009), 69% of Americans did not believe that their personal actions could make any difference, (6) complexity and uncertainty, (7) lack of strong social or political signals and the lack of leadership, and (8) self-interest of many powerful forces to maintain the status quo. At least three of the temporal and visibility challenges Moser identifies could be addressed through climate change visualizations and future scenarios in an interactive game environment: The game would allow players to make decisions and then collapse time by traveling decades into the future to see the consequences of their choices. In the future scenarios players would visually learn about the far-reaching climate change impacts of their previous choices or the long-term benefits of their mitigation measures.

In three case studies in the UK, in areas which had been struck by severe flooding, Whitmarsh, O'Neill, and Lorenzoni (2011) and Lorenzoni, Nicholson-Cole, and Whitmarsh (2007) identified similar barriers to climate change communication: individual barriers (lack of knowledge; uncertainty and skepticism; distrust in information sources; externalizing responsibility and blame; reliance on technology; climate change perceived as a distant threat; importance of other priorities; reluctance to change lifestyles; fatalism; and helplessness) and social barriers (lack of action by governments, business and industry; "free rider effect"; pressure of social norms and expectations; and lack of enabling initiatives).

The existing iconography of climate change

Doyle (2007) discusses the inherent challenges of communicating climate change through photography, for example the use of historic photos to picture a future phenomenon results in the complexity of climate change impacts remaining invisible. The standard approach has been to look for universally recognizable icons that symbolize climate change, such as glaciers and palm trees which have been popular representational motifs in landscape painting and photography (Brönnimann, 2002).

Emerging climate change communication has however begun to shift the representational frame and scholars have identified and analyzed methods that produce contradictory messaging. For example, environmental journalists play a significant role in the creative reporting on climate change which can influence "the reproduction, friction and transformation" of media logic, or the constraints and conditions of news transmission (Berglez, 2011). Scholars have also pointed to the media strategy of emotionally anchoring abstract scientific data and representing climate change in objects attached to well-known emotions of fear, hope, guilt, compassion and nostalgia (Höijer, 2010). This strategy attaches the affective images to other social phenomena, making it recognizable and comparable to other social news items. While being an effective way of engaging people in a collective response to a critical situation, it also could have the effect of reducing the response to emotionally induced paralysis. Other scholars have analyzed the construction of climate change coverage through complex narratives created in image and text. Results showed that often the visual and linguistic narratives produced confusing and contradictory claims on climate change (DiFrancesco & Young, 2011).

Today, affective images of polar bears, often appearing in news media, movies, and even commercials, have become an ubiquitous global icon of climate change. Several researchers have analyzed how iconic motifs are framed in the climate change discourse and what role icons play in picturing climate change (DeLuca, 2009; Doyle, 2007; Hulme, 2009; O'Neill & Nicholson-Cole, 2009; Leiserowitz, 2006; Slocum, 2004). Hulme (2009) summarizes the debate and highlights the criticism that the polar bear icon, "the 'poster-child' of climate change" will only reach recipients who are interested in polar bears. Furthermore, the ecological foundation for the relationship between polar bears and climate change is contested (Lomborg, 2008; O'Neill, Osborn, Hulme, Lorenzoni, & Watkinson, 2008). Polar bears in peril are even used in Coca-Cola advertisements where their representation has become part of popular culture and climate change is another vehicle to increase consumption; or as contemporary mythic discourse pretending to support environmental activism (Salvador & Norton, 2011). Hulme (2009) argues that global icons have confused the messaging of climate change instead of enabling positive, proactive attitudes and solution building. In response to the problematic visual communication of climate change through popular icons, the stated goal of the Future Delta project is to create effective locally relevant images to facilitate transformative change.

Recognizing home: the role of localized images

The literature provides multiple recommendations for more effective communication of climate change, such as further research into communication technologies and the ethical use of visualizations; a focus on the communication of specific mitigation and adaptation measures going beyond general climate awareness because awareness, information, and understanding are not enough to change people's habits of mind and practice (Moser, 2010; Moser & Dilling, 2007). For instance, dialogic, two-way forms of positive communication and collaboration seem to stimulate change more effectively (Lassen, Horsbøl, Bonnen, Grethe, & Pedersen, 2011). Planning studies in the use of multiple visual communication tools, such as PowerPoint, maps, 3D landscape visualizations, and virtual globes (Google Earth), reached similar conclusions and also recommend a mixed methods approach (Schroth et al., 2011).

O'Neill and Nicholson-Cole (2009) investigate the question of whether fear or visual and iconic representations depicting a strongly negative message are effective in motivating behavior change. Like Hulme (2009), they conclude that fear might raise public attention in the short term, but in the long term, "nonthreatening imagery and icons that link to individuals' everyday emotions and concerns in the context of this macro-environmental issue tend to be the most engaging" (2009, p. 355). As Sheppard (2012) argues, instead of shock and scare, the images of climate change impacts need to be balanced with positive imagery of proactive mitigation and adaptation solutions. This communication strategy was implemented in *Future Delta*, which focuses on positive mitigation/adaptation strategies instead of gloomy climate catastrophes.

Sheppard (2012) identifies three recommendations on how to achieve a new perception of climate change: (1) make it local, (2) make it visual, and (3) make it connected. Climate change becomes more salient by bringing *relevant information down to the local level*, putting it into a *community context that people care about, using the local landscape* to express climate change issues, and engaging citizens in *developing local solutions*. In this context, digitally produced 3D landscape visualizations are powerful tools with the potential to show how future climate change may look locally, extending the possibilities of photography into the future (Bishop, 2011; Lange, 2011; Nicholson-Cole, 2005; Sheppard, 2005). The *Local Climate Change Visioning Project (LCCVP)*, an extensive research endeavor in the community of Delta, BC (Sheppard, Shaw, Flanders, & Burch, 2008), was the point of departure for the new game initiative, *Future Delta*. The 3D photographic visualizations of the *LCCVP* were remodeled, animated, and extended within the interactive game environment of *Future Delta*.

Future Delta: Local, Visual, and Connected

The project started as an interdisciplinary effort among artists, communication designers, climate scientists, planners, and architects. *Future Delta*, the resulting interactive 3D game simulation repository, focused on a section of the Beach Grove Road in Delta, BC, which encapsulates climate change challenges, projected adaptation, technology and policy options, as well as choices and influences on a neighborhood scale. The focus of *Future Delta* was placed on building an engaging and realistic prototype of an interactive virtual environment that demonstrates possible solutions for carbon footprint reduction and flood management. This project visualized and animated a detailed neighborhood in an interactive virtual environment setting, as an initial proof-of-concept on a very limited site, i.e. a small section of Beach Grove Road. While Sheppard's approach to localize, visualize and connect climate change impacts and possible solutions through a narrative structure had been tested in local planning (Shaw et al., 2009), the current research applied the same theoretical framework to the development and implementation of an educational game. The resulting evaluation process analyzed whether 3D imagery and a virtual game environment were successful in increasing the perceived local relevance of climate change; individual responsibility; and individual change of attitudes and behavior. The evaluation used mixed methods from the social sciences to investigate student respondent perceptions of climate change and their own role in climate action quantitatively before and after playing the game; and in-depth qualitative interviews with experts about their perception of the imagery in the game as well as asking about overall understanding, learning and motivation in relation to local climate change issues.

Methods

Game design

The project comprises a game simulation with dynamic 3D visualizations of future local climate change scenarios to provide an environment for experiential learning tied to place attachment (Dulic, 2006; Shedroff, 2001; Stirling, 2008). It builds on a foundation rich in research, experimentation, and production on the topic of climate change in Delta BC (Shaw et al., 2009), while extending the previous work into a new representational platform of the virtual game. *Future Delta* enables players to explore a section of Beach Grove Road in Delta BC from a first person perspective. The player is able to wander through the 3D landscape and interact with elements in a section of Beach Grove Road that includes the beachfront, house exteriors, streetscape, yards, plants and house interiors. In addition, players can explore objects that offer potential mitigation and adaptation solutions within the game. The environment is rendered realistically with lots of details and complexity in order to create a sense of spatial and emotional immersion (Figure 1). In his research agenda for landscape visualization, Ervin (2001, p. 50) defined six landscape elements to be used in combination with each other: (1) landform, (2) vegetation, (3) water, (4) structures, (5) animals and people, (6) atmosphere including sun, wind, rain, seasons, daylight, and nighttime. Accordingly, in *Future Delta*, the 24-hour day and night sequence is represented through virtual time lapse animation that continually cycles every 10 minutes. The terrain of Beach Grove Road is based on satellite images from Google Earth and every residential house is modeled in detail, paying attention to local building types, colors, facade textures and window trims. The plants in the game are rendered in detail and resemble vegetation typical of Delta's biogeoclimatic zone. Animation and motion effects are used to further add to realistic perception of the environment, such as grass moving in the wind, leaves flowing, waves on the water, etc. In addition to the visual and 3D object representations, specialized sound is used to expand the visual effects. For example, an animation of seagulls flying overhead is accompanied by a recording of seagull cries and the environmental ambiance is enhanced by elements such as the recorded sound of wind blowing and the player's footsteps echoing on the street.

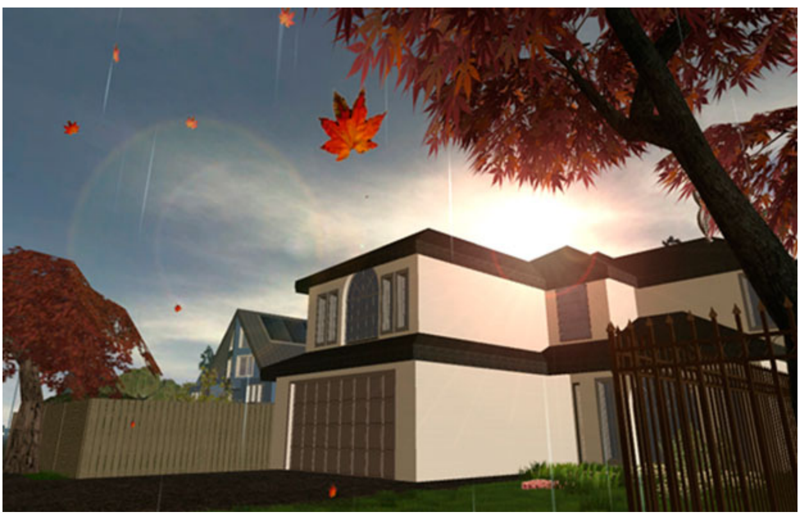

Figure 1. Landscape visualization in *Future Delta*, including iconic tree species, atmospheric effects, and dynamics such as falling leaves.
Source: Aleksandra Dulic.

The player, as a mayor of Delta, can build a new Delta community or modify the one that already exists. This is done through implementing various mitigation technologies, such as solar panels, biomass power plants, or through more dramatic urban planning and adaptation changes such as building floating homes. The player implements measures to mitigate and adapt to climate change over the period of 100 years, from year 2010 to 2110 in Delta, BC. There are 10 turns in the game, each one marking the 10-year period and collapsing time within seconds to make future consequences immediately visible.

Every technology is placed into one of three categories in the main menu: government, industry, and residential. Government upgrades are technologies that the government must help implement in order to create significant environmental change, such as CO_2 Allowances and Enforced Water Metering. Industry upgrades require the help of corporations to make eco-friendly changes, such as Wind Research and Low Intensity Farming. Residential upgrades constitute changes that the community can contribute such as Community Gardens and Window Farms. Together they create a holistic example of how one geographical area can mitigate excessive climate change through politically varied strategies. Each option that can be implemented belongs to one of these three areas and affects the player resources (money, water, and food), adaptation measures and carbon footprint. There are five resource bars the player must keep track of: CO_2, energy, food, water, and land. Through these bars, the player is able to determine how many resources they can allocate to improvements as well as holistically check their progress in the game.

Players can explore the environment in search of information which appears in a panel detailing how many resources it would cost to implement technologies, such as solar panels in the neighborhood, as well as listing the benefits and limitations associated with installing each particular mitigation/adaptation option. Players can choose different paths, such as mitigation versus adaptation, select different options, and learn about the alternate approaches through implementation, while fostering positive change through active decision-making. Each time a player builds an improvement, their resources are modified (money is spent; CO_2 is reduced, and so on). Once a measure is implemented it will appear visually in the game as a part of the environment. There are additional climate change impacts that appear with increasing frequency and intensity, such as flooding, storm surges, and heat waves that are linked to the player's carbon footprint. These environmental effects are visually represented through animation such as wind blowing, rain falling, water flooding, etc., and accompanied by related sound effects.

In addition to its effect on the environment, each improvement has an effect on the people living in the neighborhood. A player can interact with non-player characters and ask their opinions about the changes that have been made in the community. By carefully evaluating the information in order to benefit their virtual neighborhood, the player is not only playing the game, but is also learning about real local issues of climate change mitigation and adaptation strategies, challenges, and solutions. There are various end points to *Future Delta* depending on the choices the

Figure 2. Future image of floating homes as a neighborhood adapted to sea level rise. Source: Aleksandra Dulic.

player makes throughout the game. The player may fail, or succeed in mitigating and adapting to climate change in Delta. The multiple endings in *Future Delta* encourage the player to replay the game and discover alternative futures. Constructed futures such as the floating homes and condominiums (Figure 2) envelop the player in a new 3D scenario in order to visually convey the possibilities of an ecologically friendly neighborhood that could be implemented in reality.

The study: empirical test methods. The exploratory study consists of quantitative and qualitative test methods and player observation. For the quantitative test, 24 students filled in pre-/post-questionnaires before and after using a prototype of the game in a 90-minute testing session. Posters had been put up for recruitment but the questionnaire showed that only three students participated because of the poster whereas all other students were either recruited by their peers (15) or by their professor (4). All participants received free lunch as an incentive. The *Future Delta* design team observed the student participant interaction with the game prototype in a classroom setting, primarily for refining the game through the iterative design process before presenting the final prototype. It is important to note that while the game prototype focused on the Corporation of Delta, the respondents were located in Kelowna BC. The students were primarily undergraduates from the University of British Columbia, Okanagan campus, and this evaluation focused only on the impact of the interactive multimedia tools for climate change communication. For this evaluation, the impact of localized imagery relevant to local citizens was not evaluated. The data, however, will allow comparison to scheduled game evaluations of *Future Delta 2.0* in the Corporation of Delta with local citizens.

In the quantitative pre-/post-questionnaires, respondents were asked to rate their level of concern, urgency, attitudes, understanding, and sense of responsibility with regard to climate change impacts and actions; responsibility and willingness to change their individual behavior before and after playing the game (Table 1). Results from the pre- and post-questionnaires were compared through the Wilcoxon test as the nonparametric version of a paired samples t-test, performed in SPSS 20.

The qualitative test methods were in the form of expert interviews (cf. Witmer & Singer, 1998), which were conducted with 10 experts (two from Delta) from the fields of architecture, biology, geography, education, climate science, the game industry, and the Corporation of Delta. The expert interviews followed a script that ensured that all participants had a comparable 30-minute experience of the prototype game. While exploring the game, they were asked to "think-aloud" about their interaction in the game environment and their comments were audio recorded. After exploring the game, participants were asked additional questions from the interview script for approximately 20 minutes. The questions addressed the usability of the game interactions and its representational style (quality of representation), as well as asking about overall understanding, learning, and motivation in relation to local climate change issues.

Post-game play highs and lows: analyzing the survey results. The sample (n = 26) of the quantitative survey originally consisted of 26 students younger than 39 years, 13 male and 13 female, with an average self-assessment of their computer game experience set at 3.43 on a scale from 1 to 5. Students had a minimum education level of a high school diploma; two students had a community college degree, five an undergraduate and one a postgraduate degree. As we know from their apologies, eight students had to leave earlier due to a conflicting lecture and could not complete all sections of the post-questionnaire. However, there is no evidence that the dropout was a reaction to the game or the survey or caused a systematic bias. In summary, the pre-/post-questions were analyzed with a reduced sample (n = 18).

The concern about climate change in the overall sample was rated as 3.44 on a scale of 1 (no concern) to 5 (high concern) with one respondent believing that climate is not a threat at all (Tables 1 and 2). In the pre-questionnaire, the majority of respondents agreed with the statements that the federal government (15 students, or 83.3%), corporations/industry (16, or 88.9%), and environmental organizations (12, or 66.7%) were "responsible for doing something about climate change." A smaller percentage of respondents indicated that scientists (11, or 61.1%), local/municipal authorities (10, or 55.6%), community organizations (10, or 55.6%), their own friends and families (11, or 61.1%), and they themselves (11, or 61.1%) could do something about climate change (Table 2).

The pre-questionnaire exemplifies how climate change impacts are perceived as spatially and temporally remote events. The pre-questionnaires were collected on the University of British Columbia Okanagan campus that is located in the interior of the province, a geographic location more likely to have forest fires and drought rather than the flooding concerns found in Delta. However, neither forest fires nor flooding were mentioned in response to question: What images come to mind right now when you think about the effects of climate change/global warming? Four respondents wrote that polar bears were the predominant image that came to mind; three others answered "dying or dead animals." Other responses were "melting glaciers" (2x) and water pollution (2x). These responses are significant because they point to the fact that this sample of Okanagan students and/or professionals did not generally link the local changes in climate to global climate change problems. The results also appears striking as the city of Kelowna was hit by a huge forest fire in 2003, when 239 homes were destroyed and 27,000 residents had to be evacuated, and according to Woolford

Table 1. Pre-/post-questionnaire descriptive statistics.

Pre-/post-questionnaire descriptive statistics	N pre	Mean pre	SD	N post	Mean post	SD
1d. Concern: climate change/global warming observed power: 0.368	18	3.44	1.464	18	3.67	1.188
2a. Climate change concern: globally	18	3.72	1.018	18	3.89	.963
2b. Climate change concern: on local community	18	3.33	1.085	18	3.67	1.237
2c. Climate change concern: on local ecosystems	18	3.50	1.098	18	3.67	1.138
2d. Climate change concern: on immediate family	18	3.11	1.491	18	3.44	1.381
2e. Climate change concern: on future generations of family	18	3.89	1.278	18	3.83	1.150
3. When will climate change start to have serious impacts? (3 = in 50 years from now)	18	3.50	1.295	17	3.41	1.228
4. Attitude towards climate change (responses range from 1 = climate change isn't a threat to 5 = society must be radically transformed)	18	4.22	.647	18	4.33	.686
6. How does climate change make you feel? 1 = dread/fear 3 = neither dread nor optimism 5 = optimism	18	3.06	.725	18	2.83	.857
7. Do you believe actions can taken now to reduce the global impacts of climate change? 1 = Yes to 5 = No	18	2.22	1.166	18	2.00	1.029
8a. Responsibility of the federal government on a scale from 1 to 5	18	1.67	.907	18	1.56	.856
8b. Responsibility of corporations/industry	18	1.50	.857	18	1.39	.778
8c. Responsibility of environmental organizations	18	2.00	.970	18	1.67	.840
8d. Responsibility of scientists	18	2.22	1.114	18	1.94	.998
8e. Responsibility of local/municipal authorities	18	2.44	1.199	17	1.88	.993
8f. Responsibility of community organizations	18	2.50	1.150	18	2.06	1.110
8g. Responsibility of friends and family	18	2.39	1.092	18	2.11	1.132
8h. Responsibility of yourself	18	2.39	1.092	18	2.11	1.132
9. Level of understanding what would be required to reduce greenhouse gas emissions	18	3.50	.707	17	3.12	1.054
10. Knowledge about the effects that climate change may have in your local area (1 = not knowledgeable at all; 5 = very knowledgeable)	18	2.61	.850	17	2.76	.903
11. If nothing is done, when will climate change have serious impacts in your community? (3 = 50 years from now)	18	3.28	1.274	18	3.50	1.150
13. Understanding what my family and I need to do to adapt to climate change (1 = high understanding; 5 = low understanding)	18	2.72	1.127	18	2.33	1.188

et al. (2010), climate change will most likely increase the length of the fire season in many areas of British Columbia. Only five respondents thought that climate change impacts were already happening. Five respondents thought that climate change would start to have a serious impact sometime in the next 20 years, three said in the next 50 years, four indicated in the next 100 years, and one respondent thought that climate change would never have an impact.

After playing the game, concern about climate change had significantly increased with regard to local climate change impacts (n = 18, α = 0.014; Table 3). However,

Table 2. To what extent do you agree with the following statement? The following entities are primarily responsible for doing something about climate change. The table shows the added frequencies and cumulative percent of responses that agreed or agreed strongly.

Question 8: responsibility	Frequency pre	Valid % pre	Frequency post	Valid % post
Valid *n*	18		18	
8a. Responsibility of the federal government on a scale from 1 to 5	15	83.3	16	88.9
8b. Responsibility of corporations/industry	16	88.9	17	94.4
8c. Responsibility of environmental organizations	12	66.7	16	88.9
8d. Responsibility of scientists	11	61.1	14	77.8
8e. Responsibility of local/municipal authorities	10	55.6	12	70.6
8f. Responsibility of community organizations	10	55.6	11	61.1
8g. Responsibility of friends and family	11	61.1	12	66.7
8h. Responsibility of yourself	11	61.1	12	66.7

these results have to be interpreted in light of the lack of place-based connection the respondents had to the flooding issues of Delta. It is also possible that a larger sample size will reveal correlations that are not apparent yet. In order to achieve a higher statistical power when testing the significance of changes in attitude, we will ensure a larger sample of respondents in the next round of testing (*Future Delta 2.0*).

However, the result matches the other key finding that a significant increase of respondents put more weight in the responsibility of local government (the median changed from 2.44 to 1.88 on a scale from 1 (very high responsibility for local government) to 5 (no responsibility), Tables 1 and 3) than before playing the game (n = 18; α = 0.040). This finding is very promising for future game development as the *Future Delta* prototype focused on promoting climate change mitigation and adaptation solutions at the local policy level.

The game shows a strong potential to link the complexity of climate change challenges and solutions to a physical place by showing that this global phenomena has a local impact. The results also show that even though the physically located Kelowna test players were engaging with climate changes issues in the virtual Delta environment, they identified that the local Delta government has a role to play in acting on climate change. In the follow-up study, it is imperative that the evaluation of subsequent game play related to *Future Delta* will be conducted with respondents from the Corporation of Delta.

The conversation starter: qualitative expert interview results. Important suggestions for game development by expert interview respondents were implemented in the current prototype and are summarized in the following paragraphs. The main purpose of qualitative expert interviews was to contribute to the iterative game design cycle. The 10 local and nonlocal experts were recruited specifically to evaluate and contribute to the game design from the perspective of their expertise in relationship to climate change and education. The experts came from the fields of architecture,

Table 3. Wilcoxon Signed Rank Test results showing significant changes of attitudes concern about local climate change impacts, support for more radical policies, and a shift toward taking local responsibility (n = 18).

	Wilcoxon Signed Rank Test	
Indicators for the perception of climate change	*Z* value	Significance level (2-tailed)
Concern about climate change impacts		
• Globally (2a)	−1.732b	.083
• Locally (2b)	−2.449b	**.014**
• On the local ecosystem (2c)	−1.134b	.257
• For the individual and his family (2d)	−1.667b	.096
• For future generations (2e)	−.577c	.564
Perceived urgency of climate change (3)	.000d	1.000
Climate change attitude (4)	−1.414b	.157
Feelings about climate change (6)	−1.633c	.102
Support for climate action in general (7)	−1.265c	.206
Perceived responsibility of		
• Federal government (8a)	−.816c	.414
• Industry (8b)	−1.414c	.157
• Environmental organizations (8c)	−1.613c	.107
• Science (8d)	−1.186c	.236
• Local authorities (8e)	−2.058c	**.040**
• Local communities (8f)	−1.513c	.130
• Individual families (8g)	−1.633c	.102
• The individual (8h)	−1.633c	.102
Self-assessment of understanding climate actions (9)	−1.396c	.163
Self-assessment of understanding local climate change impacts (10)	−1.000b	.317
Perceived time frame of climate change impacts from now (1) to 100 years (11)	−1.633b	.102
Self-assessment of personal contribution (12)	−1.089c	.276
Self-assessment of understanding personal adaptation (13)	−1.231c	.218

The bold numbers indicate results below a significance level of 0.01 (1%), i.e. in these cases changes in perception are statistically significant.

biology, geography, education, climate science, the game industry, and the Corporation of Delta staff.

Three areas of analysis can be assessed based on the expert interviews: engagement through localized images; the perceived realism of future images and connecting the dots—learning outcomes.

Engagement through localized images. Future Delta game development was based on the premise that a response to climate change would be longer lasting and people would be more engaged if they encountered imagery showing climate change impacts in their own localities (Nicolson-Cole, 2005; Sheppard, 2012). Overall, the game prototype was seen as having the potential for engaging players. Some difference was registered between experts who were not from Delta and the two expert respondents who actually live in Delta. A long-term potential was seen in the virtual space offering an experiential framework for engagement with local climate change issues and solutions. The virtual environment of the game could be very valuable because it offers the diverse choices for players to engage in decision-making about climate change solutions, adaptation options and mitigation. However, it was noted that clear feedback mechanisms and in-game evaluation of players' choices need to be significantly developed.

With regard to the choices the players made, visual and textual feedback was seen as very important. The game prototype has many options that provide in-game visual feedback, such as build a wind turbine or a dyke, and then see visually, the result of your action in game. When the technologies were installed, players needed more feedback as to whether or not their choice brought them closer to achieving the adaptation/mitigation objectives. According to the climate scientist, the scorecard was essential, so that players immediately could see whether they were doing well or not. It was also suggested that more balanced feedback be added to each item installed, showing the negative and positive impacts of the players' decisions.

Others suggested including the whole environment in the feedback, e.g. birds, people, busy community gardens, and sounds (see the following section on landscape perception). Overall, the visual feedback reflected that most of the changes, when implemented, were not as dramatic as players thought they would be. In conclusion, in-depth feedback in the game space is one of the core tools used to orient the player in their learning and engagement. Effective feedback mechanisms must span across all aspects of the game play, such as consideration of the cognitive load and simulation, narrative structure and playability (Gee, 2007; Hwang, Hong, Cheng, Peng, & Wu, 2013). Participating experts suggested a multitude of valuable ideas, some more challenging to implement than others. The suggestions that were easy to resolve were already implemented in the next iteration of the prototype, while more complex ideas are currently under development in *Future Delta 2.0*.

Perceived realism of future images. As discussed earlier, traditional photography falls short of picturing the future impact of climate change. By extending the immersive quality of the image, 3D visualizations and interactive environments could provide an enhanced "window into the future." The *Future Delta* evaluation study asked players if they perceived the images as realistic. The quantitative survey led to a general ranking of how test players liked the virtual world overall; how highly they ranked the perceived realism of buildings, vegetation, interactions and the overall world; and how far they could recall specific items from these classes. In comparison to the survey results, the qualitative expert interviews provided insights into how the results could be interpreted. Overall, the experts perceived the quality of the architectural rendering as very high, in line with the survey results that show high rankings for the realism of 3D images of buildings.

There are multiple endings or future scenarios in *Future Delta*: one can encounter a modified Beach Grove neighborhood that closely relates to the present day or construct an entirely different environment such as a floating homes neighborhood or dense urban condominiums. When constructed, endings such as the floating homes and condominiums envelop the player in a new 3D scene in order to visually convey the possibility that something organized and ecologically friendly can be implemented in real spaces.

Two test players assessed the future scenario of floating homes and condominiums that have less vegetation as less desirable because of the high amount of concrete. The perception of concrete is an image symbol that can be easily changed with material textures. Test players generally suggested adding even more vegetation models and additional variety, which is a challenge in densely populated areas and floating architecture. In addition, test players very much appreciated the dynamic features of the vegetation models, where trees, leaves, and grass moved in response to a virtual wind. Test players also noted the animated animals such as the seagulls in the game prototype.

Another local test player from Delta suggested that additional bird sounds could easily improve the representation of diverse bird wildlife in the area. The prototype used schematic people because realistic human animation in virtual landscapes is very difficult to achieve. Like animals, having people in the virtual environment was also considered as very important. Representations of schematic people were considered as sufficient to create a feeling of community and could even communicate social functions of landscape. For instance, it was suggested that the community gardens could have more people. Atmospheric conditions, such as lighting, were considered as realistic and test players appreciated the day and night change although the time frame was dramatically accelerated. However, players were unsure about what season was being represented, since the game did not render the different seasons. At least two expert players were able to recognize the landscape as a local British Columbia coastal landscape based on the representation of vegetation such as flowers, tree types, and shrubs, representative of the area.

The game prototype could potentially be used to test player landscape preferences through statements such as "…I like this, I don't like the wind turbines." For instance, an expert player with a preference for wind turbines and renewable energy was happy to see them visualized. However, test players also identified limitations to the image realism, such as the lack of diversity in representations of vegetation, animals and people; a lack of detail in the vegetation models; as well as a video frame rate below the critical threshold of 24 frames per second. From the design perspective, the modeling and animation of a variety of animals and people posed significant technical challenges that were worked on but remained unresolved at the time of testing. In the current development of *Future Delta 2.0* effort is being made to develop a more diverse representation of people and animals.

Connecting the dots—learning outcomes. Despite the technical limitations identified above, test players agreed that it was not only engaging but also informative to actually see a broad range of future options. Even those test players, such as climate scientists and architects for whom climate-related issues are not new, said that it motivated them to think further and perhaps from different perspectives. The virtual environment was characterized as providing a challenging puzzle that makes the players think about the complexity of the climate change issues and solutions. As the game advances, it confronts players with more unconventional options, such as a future scenario featuring floating homes and encourages them to think outside of the box.

In summary, only one test player thought the prototype could actually change player behavior in real life but all test players said that the prototype was thought-provoking and made them consider alternative options for energy supply and saving, as well as the trade-offs at a local level. The climate scientist summarized the essential communication feature of Future Delta prototype in the following statement: "the game is supposed to be a conversation starter." Squire and Jenkins (2003) see value in digital games as an effective method of introducing new concepts for learners and creating meaningful links between present actions and future scenarios. This value of game play is evident in the comments of the participants who were able to visualize scenarios and choose appropriate actions in the present in order to achieve sustainable futures.

While the simulation experience aroused awareness, the indication of unchanged individual behavior is consistent with other examples of simulation-based learning that do not include facilitated follow-up (Thiagarajan, 1998). The use of this type of game-based learning would benefit from a contextualized debriefing session and/or a reflective process led by a teacher or facilitator in order to extend the new knowledge into deeper understanding (Thiagarajan, 1998). This may increase the stated intention of promoting individual behavior change through an interactive game environment.

Discussion: Limitations of the Study

The pre-questionnaire of *Future Delta* reveals that climate change is perceived as a spatially and temporally remote problem. This is consistent with other findings such as a United States survey with a larger pool of samples (Leiserowitz, 2006). The overall study points to the potential of this kind of 3D visualization in linking climate change challenges and solutions to the local. More specifically, the evaluation indicates that the use of 3D images and interactive visualizations can provide a powerful tool for representing the complexity of climate change by integrating local impacts, adaptation options, mitigations solutions, as well as individual and government actions in a serious game. The immersive quality of the 3D virtual environment provides a framework for engagement with climate change and will be further developed and tested. For the *Future Delta 2.0* follow-up project, it is recommended to increase the sample size and to assure that respondents are local but also from different age groups (as well as revising the questions to reflect the latest iteration of the game). A subsequent evaluation step will be to test *Future Delta 2.0* with local Delta players and compare the results with the study of *Future Delta* completed in Kelowna.

In the qualitative expert interviews, players noted that the choice of alternative future scenarios and the inclusion of positive mitigation and adaptation options to address negative impacts were most appreciated. This confirms Sheppard (2012), Hulme (2009), and O'Neill and Nicholson-Cole's (2009) recommendation to avoid fear mongering and to balance negative imagery of climate change impacts with positive imagery of mitigation measures.

As previously mentioned, due to the high number of dropouts the reduced sample size was very small and therefore, the statistical power of the analysis of pre-/post-questions is rather low (e.g. p went down from 0.488 to 0.368 for question 4). Furthermore, student respondents were not residing in Delta. This limitation of the study is indicative of a general limitation in using localized climate change visualization. Promoting specific adaptation measures for the Corporation of Delta may not be widely applicable in other places. Questions emerging from this study include: Is localized imagery useful or appropriate for teaching adaptation and mitigation measures to a wider audience? Is climate change addressed best at a regional, city, or neighborhood scale? Are interactive educational games with visualizations of local climate change impacts and related mitigation and adaptation options going to have a profound effect on public attitudes? Finally, it is not always possible in a setting like this to fully distinguish medium and message but the self-assessed answers gave at least an indication how far people felt affected by the one and the other. Overall, the study offers the following practical contributions to the discourse in educational gaming: virtual environments can open a space for community discussion and participation; structure experience around positive solutions; and balance the complexity of decision-making in climate change.

Conclusions

The quantitative results from the pre-/post-questionnaire suggest that 3D imagery and interactive environments can change perceptions and increase both a sense of local responsibility and support for more radical mitigation and adaptation policies. In consequence, more complex representations like this videogame might help raise support for public policies in a wider "ecosystem of change" through interactive climate change dialogue and governance, facilitated through local leadership. Despite the small sample size, we think that both quantitative and qualitative results together provide a sufficient basis for a follow up *Future Delta 2.0* project, which will involve a much larger sample of high school students residing in Delta.

Instead of visualizing climate change through the reproduction of a limited palette of iconic images (Brönnimann, 2002; DeLuca, 2009; Doyle, 2007; Hulme, 2009; O'Neill & Nicholson-Cole, 2009; Leiserowitz, 2006; Slocum, 2004), the 3D imagery and interactive game environment in this study intentionally represented climate change as local, visual, and holistic. In consequence, climate change impacts were pictured locally and framed through the proactive message that individual and local community mitigation/adaptation options are possible. Bringing the realities of climate change to the local community level through images is technically and scientifically challenging. However, the results show that the connection of climate change impacts with local, i.e. personal and municipal concerns, is key. Therefore, it is suggested that future research will engage local communities in an iterative game design process and compelling game play with the assumption that the players, by virtue of their involvement, will want to be more personally connected to their municipal concerns around climate change.

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Note

1. http://futuredelta.ok.ubc.ca.

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