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Research Paper

Evaluating presentation formats of local climate change in community planning with regard to process and outcomes

Olaf Schroth[a,*], Ellen Pond[b], Stephen R.J. Sheppard[b]

[a] The University of Sheffield, Arts Tower, Western Bank, Sheffield S10 2TN, United Kingdom
[b] Collaborative for Advanced Landscape Planning (CALP), University of British-Columbia, UBC's Centre for Interactive Research on Sustainability, 2321-2260 West Mall, Vancouver, BC V6T 1Z4, Canada

HIGHLIGHTS

- Visualizations in a climate change planning process were assessed as very helpful by local stakeholders and residents.
- Visualizations presented in a virtual globe facilitated understanding and increased awareness during an open house.
- 22 months later most decision-makers still remembered or used the visualizations.
- Visualizations embedded into process informed policy, operational and built changes.
- Although the virtual globe presentation format was effective during the process it was less so in the long term.

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ABSTRACT

This study synthesizes two evaluations of a local climate change planning process in a rural town in British Columbia (Canada), which was supported through landscape visualizations. First, the impact of the visualizations, based on scientific environmental modeling and presented in three different presentation formats, verbal/visual presentation, posters and a virtual globe, was evaluated with regard to immediate impacts during the process. Second, the long-term impacts on decision-making and actual outcomes were evaluated in a retrospective evaluation 22 months after the end of the initial planning process. Two results are highlighted: according to the quantitative pre-/post-questionnaires, the visualizations contributed to increased awareness and understanding. Most importantly, the retrospective evaluation indicated that the process informed policy, operational and built changes in Kimberley, in which the landscape visualizations played a role. The post interviews with key decision-makers showed that they remembered most of the visualizations and some decision-makers were further using them, particularly the posters. The virtual globe seemed to be not a "sustainable" display format suitable for formal decision-making processes such as council meetings though. That may change with the further mainstreaming of visualization technologies or mobile devices. Until then, we recommend using display formats that can be re-used following a specific planning event such as an Open House, to ensure on-going support for effective decision-making over the longer-term.

1. Introduction

1.1. Climate change communication in urban and landscape planning

Climate change is a complex problem with impacts and interactions at global to local scales. Mitigation alone will not be sufficient to ensure a sustainable future: local communities need to adapt their planning to climate change impacts and adaptation (IPCC, 2014). While political and economic frameworks may be developed at international and national levels, local communities will play a key role in the implementation of both mitigation and adaptation actions (Moser & Dilling, 2007). Barriers to the communication and integration of climate change into spatial planning include the complexity of climate science and long time horizons (Blanco et al., 2009; Moser & Dilling, 2007). Climate change is only meaningful in community planning if the potential impacts and response options can be understood and handled within local planning processes and policy development (Batty, 2010); community vulnerabilities and possible climate change impacts need

* Corresponding author. Tel.: +44 1142220615.
E-mail address: O.Schroth@sheffield.ac.uk (O. Schroth).

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to be relevant to local decision-makers, stakeholders and citizens (O'Neill & Hulme, 2009). However, the long time scales do not align well with human cognition, which generally seems to be limited to anticipating 15–20 years into the future or 50 years at most (Tonn, Hemrick, & Conrad, 2006). These complex spatial and temporal dimensions partially explain why climate change has only recently begun to be addressed in local Canadian land use policies (e.g. Carlson, 2012). If they are to be effective, landscape and urban planning processes need to adopt visualization tools that make the spatio-temporal dimension of climate change apparent at the local scale and in the context of locally relevant themes.

1.2. Objectives of this study

This paper presents two evaluations: a process evaluation and an evaluation of the later outcomes of the Kimberley Climate Adaptation Project (KCAP). The paper explores different presentation formats for visualization media (see Gill, Lange, Morgan, & Romano, 2013), i.e. oral/verbal presentation, posters and virtual globes with multi-dimensional interaction (defined as spatial, temporal and thematic navigation), in terms of (a) whether they can have positive immediate impacts on local climate change planning processes, and (b) how the visualization media support long-term decision-making outcomes from those processes. Drawing on Pond et al. (2012), immediate impacts are defined as those changes for participants that occur during or immediately following the use of 3D landscape visualizations and tools in a process, including: changes in awareness, attitude and understanding (Bishop, Pettit, Sheth, & Sharma, 2013; Walter, Helgenberger, Wiek, & Scholz, 2007); affective responses (Sheppard, 2005; van Lammeren, Houtkamp, Colijn, Hilferink, & Bouwman, 2010); and new scientific insights (Bishop et al., 2013; Walter et al., 2007). The study fits into the framework for visualization evaluation suggested by Bishop et al. (2013), who used similar tools (based on the Google Earth API). Our study differs in its real-world application with the public as participants and by adding a novel retrospective component to assess effects on planning processes and decision-making. The specific planning process itself has already been studied and will be briefly summarized in this paper to enable a comparison with the later evaluation of outcomes.

The first objective of the process evaluation was to assess the preferences of participants for the different presentation formats: slide presentation, posters, and virtual globe. *The second objective* of the process evaluation was to measure any immediate changes in awareness about local climate change impacts and an increased understanding of the links between land use and climate change vulnerabilities during the KCAP's public Open House and in the process outputs, i.e. recommendations and plan documents. Until now, this quantitative pre-/post comparison has only been analyzed for an unpublished project report (Schroth, Pond, Muir-Owen, Campbell, & Sheppard, 2009). The *third objective* was to assess user feedback on visualization utility and specifically the multi-dimensional interaction for exploring spatio-temporal dimensions of climate change. These results have been previously published in Schroth, Pond, et al. (2011), and will be briefly summarized.

The novel *retrospective element* is part of a longitudinal study revisiting the long-term effectiveness of visualizations in planning processes, filling a gap in landscape visualization research identified by Bishop et al. (2013) and described below. The definition of "longitudinal studies" varies across disciplines; in this paper we are referring to qualitative longitudinal policy studies (see Holland, Thomson, & Henderson, 2006). Rist (1994) defines a longitudinal policy study as covering different phases of a policy cycle including policy formulation, implementation and accountability. Elliot, Holland, and Thomson (2008) further distinguish retrospective studies as a common and very efficient way of collecting longitudinal data, i.e. looking back at past events and collecting data about the impact such past events have had over time. In this paper, we used two formal data collection periods: during the initial event and process in 2008–2009 and during follow-up interviews in 2011. According to Elliot et al. such studies could be described as collecting data "retrospectively as part of an on-going prospective longitudinal study" (2008: 229). With regard to Bishop et al. (2013), Faludi (2000), Larsen and Gunnarsson-Östling (2009), Robinson and Tansey (2006), and Walter et al. (2007), the *objectives for the longitudinal study element* are:

(1) Evaluate whether key decision-makers still remember the visualizations.
(2) Determine the uptake of spatial planning and geo-visualization tools. Is there any difference between the virtual globe (multi-dimensional interaction) and other presentation formats in their long-term use?
(3) If so, did the visualizations add depth to the deliberation about local impacts and response options?
(4) Did the visualizations add to an increased capacity of participants to act?
(5) Evaluate retrospectively whether (a) the KCAP process in general and (b) the visualizations in particular had an impact on local decision-making processes.
(6) Evaluate retrospectively the actual outcomes such as policy or operational change and whether they suggest transformative or incremental change toward a shared goal.

A major limitation of such an explorative longitudinal study is the variety of external, potentially confounding variables. The follow-up interviews provided some indications of influences beyond the visualization tools, such as policy variables and the role of local champions, in shaping final outcomes. However, these interactions were not formally assessed in the final analysis.

2. Visualizations as tools for communicating climate change planning options

As tools for participatory local planning, landscape visualizations have been shown to help people understand possible future or alternative conditions (e.g. Al-Kodmany, 1999; Bishop & Lange, 2005; Danahy, 2001; Lange, 2001; Lewis, 2012; Orland, Budthimedhee, & Uusitalo, 2001; Pettit, Raymond, Bryan, & Lewis, 2011; Salter, Campbell, Journeay, & Sheppard, 2009; Schroth, Wissen-Hayek, Lange, Sheppard, & Schmid, 2011) and to "geodesign" these futures (Steinitz, 2012). In addition, several authors have addressed the potential of local landscape visualization as a tool specifically for improved communication of climate change implications (Dockerty, Lovett, Appleton, Bone, & Sünnenberg, 2006; Nicholson-Cole, 2005; O'Neill and Hume, 2009; Sheppard, 2005). Landscape visualizations of iconic local places function as a shared platform to integrate and communicate scientific data and local knowledge across multiple climate impacts and mitigation/adaptation strategies (Cohen et al., 2013; Sheppard, 2012). Recent work (e.g. Bishop et al., 2013; Cohen et al., 2012; Nicholson-Cole, 2005; Pettit, Bishop, Sposito, Aurambout, & Sheth, 2012; Sheppard, 2012) has thus established early evidence and principles to support the role of landscape visualization together with climate change scenarios in community engagement and decision-making.

Until recently, the body of work referred primarily to static landscape visualizations. While these have examined time sequences, various spatial viewpoints, and integrated or layered spatial datasets, only a few studies have now started to specifically evaluate the affordances of interactive landscape visualizations to communicate long-term climate change impacts (Bishop et al., 2013; Pettit et al., 2012; Schroth, Pond, et al., 2011) and the uncertainty of climate change visualization (Niño Ruiz, Bishop, & Pettit, 2013). Multi-dimensional interaction, i.e. the extension of spatial navigation through time and by theme, is especially well developed in virtual globes/geovisualization software, with computer interfaces that use the globe metaphor to allow users to "zoom" between local and global scales and provide specific navigation features for "time travel" and layers for thematic navigation (Sheppard & Cizek, 2009).

Multi-dimensional interaction may thus offer new ways for users to assess climate impacts and vulnerabilities with regard to complex spatio-temporal data, e.g. snowpack change over time, by providing seamless, dynamic transitions across space and time, with free choice of viewpoints and access to an almost unlimited number of views/images or animated sequences. Sheppard and Cizek (2009), in reviewing benefits and risks of virtual globes, note the instant access to data layers, metadata, and realistic and accurate imagery with virtual globes, via an interface with real-time response to queries or navigation choices. Other possible benefits include the potential for stimulating interest among lay people, with considerable potential for use as 'bottom-up' participation tools and user-generated data. However, questions have been raised about difficulties in users' cognition, such as visualizing abstract concepts in space (Craglia et al., 2008), the imposed heavy cognitive loads (i.e. the number of interactions the human brain has to process simultaneously) (Ware & Plumlee, 2005) and the risk of misinterpretation in a non-facilitated context (Sheppard & Cizek, 2009). Some research on interactivity has been done in cartography for atlas systems with multi-dimensional navigation (Hurni, 2008) and in human computer interaction (HCI) experiments (Lewis, 2001). Bishop et al. (2013) also introduced controlled "laboratory" settings like in HCI to landscape visualization research; however, few evaluations of visualizations and virtual globes as used in real-world processes and planning settings exist.

Evaluation may focus on technical aspects of the tools: functionality, utility, and comprehension (Bishop et al., 2013) or interactivity and preferred visualization media (Gill et al., 2013). In comparison, longitudinal evaluation offers an opportunity to assess impact on decision-making and outcomes rather than immediate impacts, and has been called for by Bishop et al. (2013). Bishop et al. note both the potential power of visualizations and the difficulties in attribution of effect to direct cause: "Over an extended period, effective visualization tools may trigger changes in awareness or changes in work practices that lead to profound outcomes, and direct links back to the visualization may be difficult to establish" (2013: 219). In addition, real-world evaluation must deal with "messy" variables – cultural, political contexts, etc. – and risk presenting results that are not generalizable (Bishop et al., 2013).

3. Methods

3.1. Study context, participants and scenario approach

The Kimberley Climate Adaptation Project (KCAP), a community-led initiative to Learn, Share, and Plan about local climate change impacts (Liepa, 2009), provided a case study in which to test the use of different presentation formats including virtual globes. With a population of approximately 6000, the City of Kimberley typifies small rural communities in British Columbia (Canada) that need to plan for a range of climate change related issues and impacts, including rising snowlines and changing hydrological regimes, forest pest infestations, and increasing fire season lengths. The KCAP project ran over 2008–2009, culminating in a community Open House and resulting in an adaptation plan with over 70 recommendations for further action on water, forests, and tourism.

Aerial photos, development proposals, future snowpack modeling, flood risk, mountain pine beetle susceptibility (Fig. 1) and a fire model were integrated into GIS and a virtual globe model (for the modeling and geo-visualization workflow see Schroth, Pond, & Sheppard, 2012). These thematic layers enabled questions about potential vulnerabilities now and in the future with climate change to be asked, and options (scenarios) for the community's future adaptation as well as greenhouse gas mitigation to be explored.

3.2. Presentation formats

The projected climate change impacts, scenarios, and KCAP recommendations were presented at a Community Open House in 2009, using three presentation formats: a verbal/visual slideshow presentation (i.e. the facilitator leading through a PowerPoint presentation); posters; and a hands-on (i.e. user-directed with mouse) virtual globe station (Table 1). The slideshow contained 39 slides with 19 static landscape visualizations, eight maps, four diagrams and four (map) animations controlled by the presenter. It was projected onto a large screen in front of the audience. The eight color posters contained 10 landscape visualizations, 11 maps and four diagrams and were printed in A1 and put on the wall during the open house. The virtual globe contained a 3D city model, seven base data layers, multiple 3D icons (van Lammeren et al., 2010) for viewpoints and points of interest such as historic forest fires or debris flooding, and between five and 10 map layers for each topic (please see the linked KML files). By turning layer sets on and off, it was possible for the virtual globe users to navigate through the different themes in the virtual globe or compare thematic layers. It was running on a computer station in the room and interested participants could explore it with the help of a researcher (the virtual globe model is described in more detail in Schroth, Pond, et al., 2011). After the open house, a report was written for dissemination to funders and city staff. Despite the different presentation formats, the content was always based on the same geospatial data and landscape visualizations, and addressed the same themes. Temporal change was presented with the help of animations in the presentation, as map series on the posters (resulting in a higher number of maps on the posters) and using the time slider in the virtual globe (Fig. 2).

3.3. Process evaluation

The research design was exploratory and based on the case study methodology (Francis, 2001). The benefit of the case study method is that it allows for testing in a realistic planning context. On the other hand, control over the research environment and research variables is limited, due to the need to fit the research to a real community planning process. In order to provide robust results, mixed quantitative and qualitative methods were applied (as suggested in Bishop et al., 2013) in a three-stage process evaluation and a retrospective evaluation of the longitudinal impact on decision-making 22 months later (see Section 3.6).

The three stages of the Open House process evaluation were:

- Pre-/post comparison of questionnaires with analysis of changes in participant awareness about climate change and their understanding of the links with land use changes.
- Analysis of subjective ranking by participants of the visualization media used in the Open House.
- Structured in-depth user interviews documenting the experience of using multi-dimensional navigation within the virtual globe station; video- and recorded documenting the computer screen

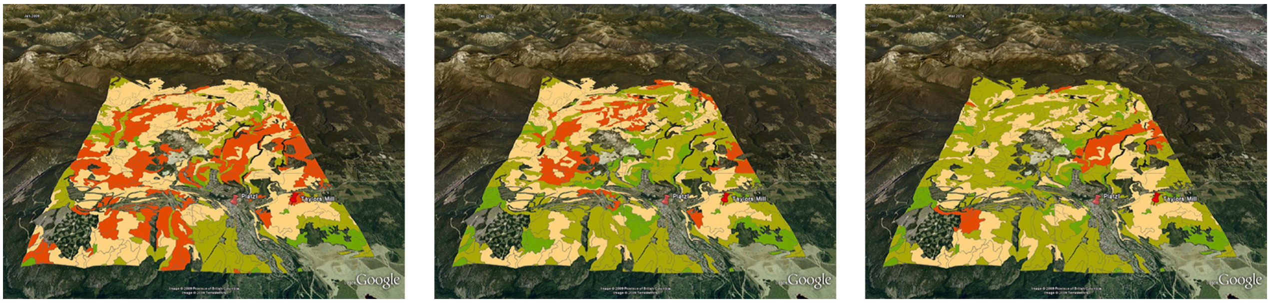

Fig. 1. A series of maps produced in 2008 predicting mountain pine beetle susceptibility of forest stands for the next 80 years was presented in a virtual globe using zoom, time slider and layer functions. This selection of three images shows current and future Mountain Pine Beetle susceptibility for the years 2009, 2030 and 2070. The dark orange (dark shaded in black/white) areas represent high susceptibility, while the light orange (light shaded in black/white) represent medium susceptibility. The green areas (medium shaded in black/white) are low or very low susceptibility. For 2009–2010, the actual infestation was close to the predicted susceptibility (geodata© 2009 Google).

Table 1
Categorization of media components and presentation formats used in the Kimberley Open House presentation.

Presentation formats	Media components					
	Text	2D maps, aerial photos, diagrams	Landscape visualizations (static)	Landscape visualizations (live animation)	3D icons	Interactive self-guided exploration
Posters	Yes	Yes	Yes	No	No	No
Verbal/visual presentation	Yes	Yes	Yes	Yes	No	No
Virtual Globe station • Spatial nav. • Time slider • Layers • Pop-ups	Yes	Yes	Yes	Yes	Yes	Yes

and user hand/mouse interactions at the time of the structured interviews, during the open house.

As described in further detail in Schroth, Pond, Muir-Owen, Campbell, and Sheppard (2009), 46 people attended the Open House, of which 36 completed the pre-questionnaires and 38 completed the post-questionnaires. 11 respondents chose to not provide personal data; the remaining sample was equally distributed with 13 males and 14 females. The age representation was: <20 two; 20–29 two; 30–39 five; 40–49 seven; 50–59 nine; and >60 two. Self-reported experience with computer visualizations varied: only one person reported having “no experience at all”; seven reported “very little”; six “some but not much”; 13 “quite a lot”; nobody assessed themselves as “very experienced.” Ethnicity was not included in the questionnaire; the community is predominantly euro-Canadian.

3.4. Analysis of questionnaires

The pre-questionnaire ($n = 36$) asked participants to rate their concern level regarding climate change in comparison to other global issues, their knowledge about the global and local impacts

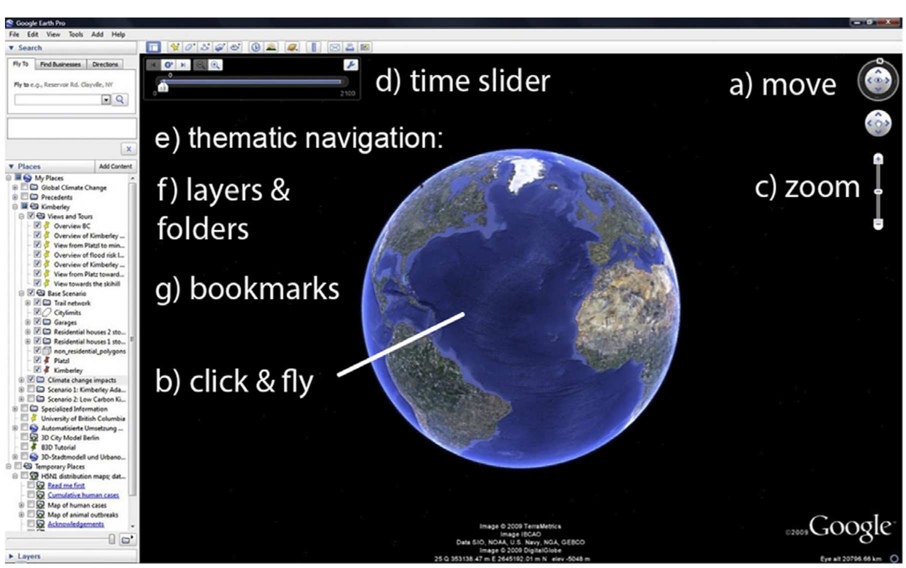

Fig. 2. Spatial navigation in Google Earth: (a) move, (b) click & fly, and (c) zoom; temporal navigation: (d) time-slider; (e) thematic navigation: layers and folders, and (f) bookmarks and tours (geodata© 2009 Google).

of climate change, and their understanding of links between climate change and land use using a five-point Likert scale. The post-questionnaire ($n = 38$) contained the same questions, allowing comparison of pre-/post-questionnaires by 36 respondents (using the paired-samples t-test for related samples because the responses were normally distributed) to show whether participants rated their levels of awareness about climate change and understanding of the links between climate change and land use differently after the public Open House.

Subjective assessment is a well-established empirical method particularly in participatory action research: respondents are asked to assess their perceived level of understanding, i.e. their subjective assessments (see Bishop et al., 2013 who used a similar approach). In the post-questionnaire, respondents were asked to assess how helpful different presentation options were for the understanding of local climate change impacts, links to land use, and mitigation and adaptation measures; to rate the overall helpfulness of the combined visualizations; to rank the presentation formats; and, to rank the multi-dimensional interactive features of the virtual globe. The full questionnaire is archived online under http://www.lviz.org/uploads/KCAP%20Questionnaire%20final%20version.pdf. The quantitative results were analyzed with descriptive and frequency tools (mean, standard deviation, variance, minimum and maximum) in the statistical analysis software IBM SPSS Statistics 20.

3.5. Analysis of interviews and video-taping of users at the virtual globe station

In addition to the quantitative pre-/post-questionnaire, structured qualitative interviews were conducted with 17 users ($n = 17$) who explored the hands-on Google Earth model, asking them to report what they saw and how they interpreted the information. The sessions (lasting up to 20 min per person) were videotaped (computer screen and hand/mouse) and audio-recorded.

The qualitative feedback and transcripts from the virtual globe station interviews were analyzed and classified into 40 codes using the Qualitative Data Analysis & Research Software Atlas.ti. The main categories of codes such as context, impact and technical issues were formulated with regard to research question and literature and further elaborated in sub-categories derived from the data. Reliability was increased through data triangulation, i.e. comparing results from four different data sources to determine consistency (cf. Bishop et al., 2013). Rankings and responses under (a) Question 8 in the post-questionnaire ("Please rank the [interactive] features [shown below] in order of their helpfulness to you in understanding climate change adaptation and mitigation") and the following open-ended question were compared to (b) the videotape of user-globe interactions at the virtual globe station, (c) the audiotape of the station sessions and (d) structured interviews. If a statement is confirmed through two or more sources of evidence, the derived result has a higher level of confidentiality than isolated evidence.

3.6. Retrospective data collection as part of the longitudinal evaluation

In April 2011, 22 months after the Open House, phone interviews were conducted with seven key decision-makers in the community: two (out of seven) city councillors from different sides of the political spectrum, a city officer responsible for planning, a senior member of the fire department, a consulting fire ecologist, the facilitator of the initial KCAP, and a community representative who is also locally active in two environmental NGOs. They all participated in the KCAP process, on the local working group or providing input to the process. While this is a small sample, it represents about half of the working group members, especially those with decision-making responsibilities, and also represents the range of working group stakeholder types. In late 2013, Kimberley's Integrated Community Sustainability Plan ICSP (Centre for Sustainability Whistler, 2011) and other recent planning outcomes such as the Mark Creek Flume Flood Management and Stream Rehabilitation Project were reviewed and compared to the interviews in a document analysis. The phone interviews were semi-structured, following a script that encompassed both questions about the process and, where possible, more specific assessments of visualization tools used. It also included both the interviewees' response in hindsight to the original process, as well as subsequent uses and outcomes. All interviews were audio-recorded and transcribed before analysis through coding in the Atlas.ti software. Six codes were derived from the evaluation goals: (1) references to visualizations from the KCAP, (2) how tools were used for planning tasks, (3) change of awareness, (4) change in individual knowledge and capacity to act, (5) impacts on decision-making practice, and (6) physical outcomes in the built environment. References to the visualizations (1) were cross-linked to issues identified in any of the other codes where relevant, since we expected some interaction between the continued use of the visualizations and the decision-making process. While variables had been controlled as far as possible during the open house, the retrospective data collection was cognizant of additional factors that may have impacted long-term outcomes, although these were not subjected to formal analysis.

4. Results of the process evaluation

The following section summarizes results from the questionnaires (quantitative and qualitative) and the virtual globe station interviews during the Open House. Results are presented on immediate impact on awareness, attitudes and knowledge, and reported preferences for and utility of presentation formats. Results on long-term outcomes are presented in Section 5. In the following, the term "respondents" refers to participants quoted from the questionnaires, and "users" to the subset of participants quoted from interviews at the virtual globe station. Longitudinal study participants are referred to as interviewees.

4.1. Immediate changes in awareness, attitudes and knowledge during the Open House

Mean results show already high initial levels of concern on a five-point Likert scale (the average of all means is 4.56, see Table 2). Respondents' subjective assessment of their concern about climate change impacts on the local community, local ecosystems and future generations increased significantly between pre and post questionnaires, with a significance level of 0.05. Subjective assessment of climate change concerning their families and understanding the link between climate change and future land use development showed a significant increase with a significance level of 0.01 (Table 2).

4.2. Visualization utility and preferred media

34 out of 38 respondents rated the visualization material as helpful or very helpful in understanding climate change adaptation and mitigation options in Kimberley. Both posters and virtual globes had fairly high median rankings of 2. The virtual globe ranked first 16 times and last 11 times (out of 38), showing a bimodal distribution (Schroth, Pond, et al., 2011). Posters ranked first 12 times and only once ranked last. The (almost) one third of respondents who ranked the posters first ranked the virtual globe last on average, while respondents who liked the virtual globe also

Table 2
Paired-samples statistics and paired-sample *t*-test for self-assessed ratings of concern about climate change and assessment of climate change and land use links before and after the Open House (pre-/post-questionnaire).

Paired samples statistics

Concern about climate change		Mean	*N*	Std. deviation	Std. error mean
Pair 1	Pre concern globally	4.89	36	.319	.053
	Post concern globally	4.92	36	.280	.047
Pair 2	Pre concern about local community	4.56	36	.504	.084
	Post concern about local community	4.72	36	.454	.076
Pair 3	Pre concern local ecosystems	4.61	36	.494	.082
	Post concern local ecosystems	4.78	36	.422	.070
Pair 4	Pre concern family	4.22	36	.760	.127
	Post concern family	4.47	36	.654	.109
Pair 5	Pre concern future generations	4.69	36	.624	.104
	Post concern future generations	4.86	36	.424	.071
Pair 6	Pre assessment of how strongly climate change and future land use are linked	3.74	34	.898	.154
	Post assessment of how strong climate change and future land use are linked	4.24	34	.431	.074

Paired samples test

Concern about climate change		Paired Differences 95% Confidence Interval of the Difference Upper	*t*	*df*	Sig. (2-tailed)
Pair 1	Level of concern globally	.029	−1.000	35	.324
Pair 2	Level of concern about local community	−.039	−2.646	35	**.012**[*]
Pair 3	Level of concern regarding local ecosystems	−.039	−2.646	35	**.012**[*]
Pair 4	Level of concern regarding family	−.081	−3.000	35	**.005**[**]
Pair 5	Level of concern regarding future generations	−.039	−2.646	35	**.012**[*]
Pair 6	Assessment of how strong climate change and future land use are linked	−.199	−3.384	33	**.002**[**]

n.s. = not significant ($p \geq 0.05$).
[*] Significant $p < 0.05$.
[**] Very significant $p < 0.01$.
[***] Highly significant $p < 0.001$.

liked the posters. Given the real-world Open House where a variety of media were employed, it is possible that participation in the hands-on station may have had an effect (positive or negative) on virtual globe rankings. In the open feedback part of the post-questionnaire, 25 comments were received from 25 different respondents on the visualizations and virtual globes specifically. Fifteen of these comments were positive about the use of visualizations including virtual globes, e.g. “It is a great tool. Very applicable for community planning process.” Three respondents stated that they had not learned much from the visualizations or that this was not the right medium for them: e.g. “an awful lot to absorb in such a short time. [. . .] For older people, probably visuals are too much too fast too hard to follow. Younger people more accustomed to computer visualizations probably absorb all this very readily.”

4.3. User experience of the virtual globe model

The interview data from the virtual globe stations suggests that multi-dimensional interaction in particular aids in understanding climate change impacts and risks such as extended forest fire seasons and flood risk: “the forest fire one I thought was really great. [. . .] I don’t think people realize how often they’ve happened so especially when they hear about interface [. . .] how serious of a threat it is to town.” A major outcome in terms of understanding came from the exploration of mountain pine beetle susceptibility and flood risk. During the Open House presentation, the researchers first used the susceptibility model to demonstrate the visual impact of future pine beetle spread; then after an overlay was added of pine beetle endangered forest stands and flood risk, it became obvious to users that the risk of debris flooding will increase: “Flood risks [. . .] look at Mark Creek. [. . .] So this is based on a scenario where [. . .] a flood would occur because of [. . .] a jam on a bridge here [. . .].” (see Fig. 3). In this point, the interview data matches and supports the questionnaire feedback (data triangulation).

The various themes have very different time scales: eight hours for the fire spread model and up to 100 years for urban development and mountain pine beetle cycle. Different temporal phenomena and time scales need to be distinguished in the context of risk assessments. While frequency of forest fires was visualized in a static map, progression (fire spread model, urban development) was interactively animated as a time-lapse sequence with the Google Earth time slider. Interview transcriptions show that both visualizations were understood correctly, although the time slider animations were more dramatic. One user reported that the “fire viz. was most powerful – [you] could feel it in the room” (the role of drama in landscape visualization is discussed in further detail in Sheppard & Cizek, 2009).

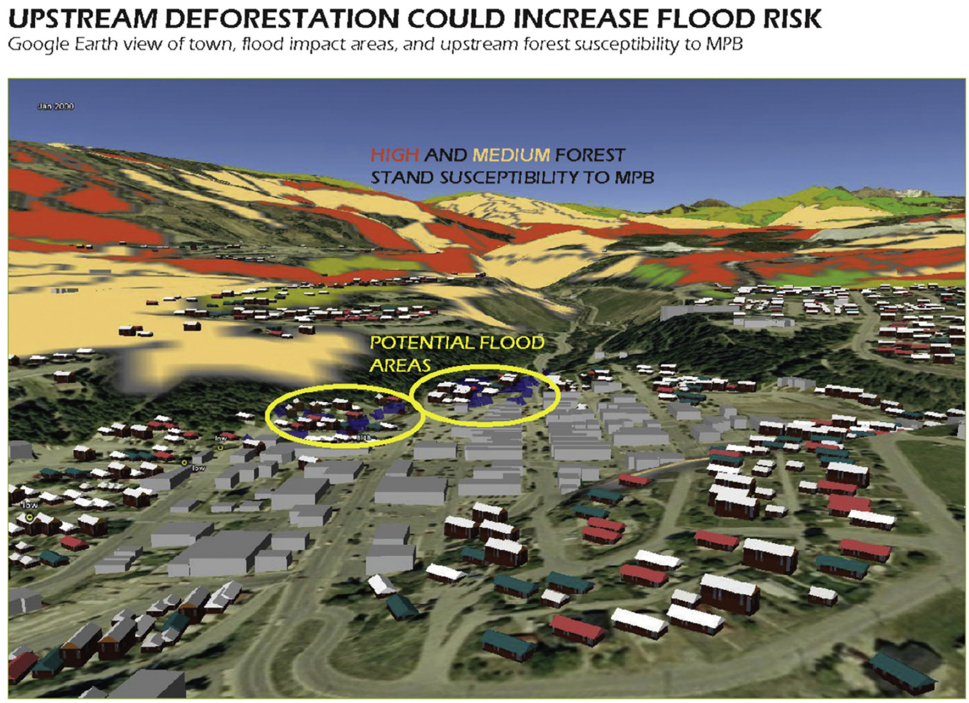

Fig. 3. This figure shows the Kimberley town center with an overlay of potential flood areas as identified in the municipal flood risk study (highlighted through circles) and the areas for future mountain pine beetle susceptibility, derived from the susceptibility model (orange/dark shading in black/white for high susceptibility and yellow/light shading in black/white for medium). It led to the conclusion that increased mountain pine beetle damage will increase the amount of dead wood and therefore increase flood risk from debris jams at the highlighted bottlenecks (geodata© 2009 Google). (For interpretation of the references to color in this text, the reader is referred to the web version of the article.)

5. Longitudinal evaluation

The evaluation of long-term impacts of both the case study process and its embedded visualization tools considered the following dimensions:

- Interviewees' recall of the presentation in the original process and/or in subsequent use, as an indicator of vividness and influence on current thinking.
- Interviewees' perceived assessment of the added value/effectiveness of the visualizations and visualization development process in the KCAP.
- Reported use of spatial planning and presentation formats including their perceived utility, reported uptake and on-going use.
- Interviewees' views of contribution to decision-making, and increased capacity of decision-makers to act.
- Actual outcomes in terms of policies, and the built environment, including transformative or incremental change toward a shared goal.
- Unexpected findings.

5.1. Recall of visualizations and perceived added value

All interviewees remembered the visualized scenarios in general; two interviewees described the most influential images in detail. The interviewee who had copies of the posters on display at work and who used the virtual globe after the Open House provided the most detailed description of the material, covering eight specific thematic visualizations. One interviewee missed the presentation; one interviewee did not recall the visualizations in any detail. However, five interviewees (all except the councillors) referred to the animation of the fire spread model.

For example, one interviewee not only referenced the fire sequence, but also the mountain pine beetle, watershed and revisioning the downtown/proximity to groceries. All the interviewees noted that the visualizations "added value" to the adaptation planning process.

5.2. Perceived increase in awareness and understanding, adding depth to on-going deliberations

Interviewees had different conceptions of how far awareness among local residents, city council and stakeholders has changed as a consequence of the KCAP and the visualizations. The councillors thought that the multi-dimensional visualizations did have an impact on the city Council overall, although the virtual globe format might not be as suitable for older users. Even the more skeptical councillor stated, "the process [. . .] really enlightened me and I can say opened my eyes about [. . .] climate change." Two interviewees explained that they were already well informed about climate change and therefore, the visualizations did not change their awareness but may have added details to their understanding; one stated that he had thought more about what can be done since the KCAP. With regard to the general public, most interviewees thought that the KCAP had informed the public but did not significantly change public opinions.

Three interviewees emphasized that the temporal dimension was key, i.e. being able to see past events and changes 50–100 years into the future with linkages between the topics.

> "The key thing is just being able to talk about [. . .] very specific things that we learned as a result of [the] visualizations . . . fire risk, by looking at mountain pine beetle in watershed. It provided more detail, more detailed understanding, a richer understanding of what was going on, which then makes it easier to communicate and articulate further."

Several interviewees noted that the collaborative client-centered process (i.e. that the visualizations had been developed

Fig. 4. Landscape architecture conceptual design proposal for the adaptive redesign of the Kimberley flood risk area – a planning outcome of the KCAP and visualized in the virtual globe.
Credit: Muir-Owen and Pond (2009).

together with the stakeholder working group) was important, as was having an introduction or mediation:

> "It's just really good [that] before people go into one of these globes that there's some introductory material to say what it is and what it isn't."

5.3. *Reported use of tools: utility, uptake and on-going use*

One interviewee stressed that the forum in which people are engaged is important: is it a public meeting, is the participation process a one-off event or on-going and who has access?

> "I think that using visualizations like that are a good idea. I think you can get people to respond and react to them more than just a bunch of text on a piece of paper. The limitation is how do you get people to look at it? Where are your forums to allow that to happen?"

Another interviewee commented: "how do you keep doing it on an on-going basis to reach all the other people that haven't seen it?"

Relevant posters were actually displayed at the city booth at a Green Building conference the following year and permanently displayed on a wall at City Hall for further reference in everyday planning. The posters are used in "coffee conversation," such as:

> "The design for Mark Creek looked to deal with the concrete flume and the flood risk there. We looked at that [poster] quite a bit. And the other one that's been a really good one was the Green River vision. We used that to talk about some of our trail planning and initiatives and stuff that we've been doing."

A second interviewee reported using the multi-dimensional visualizations "extensively" after the Open House: in a fuel management workshop, when talking about landscaping, irrigation, xeriscaping, etc. and as argument to promote a water conservation scheme and sprinkler bylaw. This interviewee had also contacted the researchers asking to convert the model from the virtual globe format into a time-lapse wildfire video and fire mitigation poster.

Two interviewees used the virtual globe on their own following the Open House, but both reported technical difficulties and glitches with the technology. They thought that the technology was not reliable enough, especially for a larger setting such as a council meeting at city hall. One interviewee had not re-used any visual materials but "was keeping them in the back of her head." The posters and to a lesser degree the final KCAP report, produced following the Open House, were described as the long-term legacy of the project; one interviewee stated that "actual output materials are needed to make a long-term impact beyond the end of the actual process."

5.4. *Contribution to the decision-making processes in council and operations*

One interviewee noted that there are more local champions following the process now than before the KCAP. Another spoke to the changes at the Council and staff level:

> "When we first started this process I think climate change was just a word. But I think now that we've got into it, and again our staff continues continually [to] remind Council that we have to do this. As a result, the Council is now more pro-active."

For example, two interviewees emphasized that primarily "local champions" drive change; the visualizations were powerful talking points supporting transformative change but unlikely to work on their own. As an additional caveat, one interviewee noted that

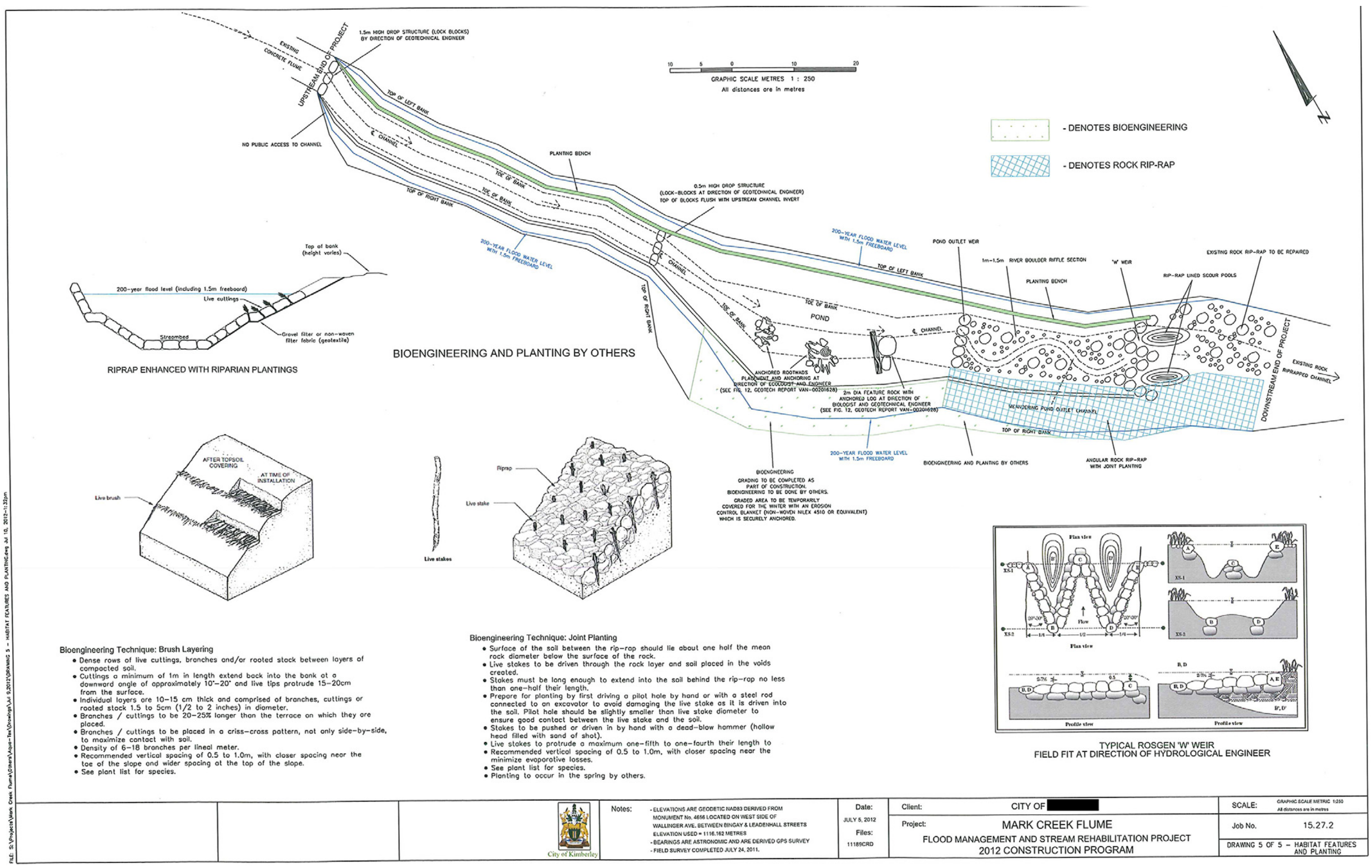

Fig. 5. Implementation of the Mark Creek Flume Flood Management and Stream Rehabilitation Project 2012 Construction Program – Habitat Features and Planting. Source: City of Kimberley, retrieved on January 19, 2014 from https://kimberley.civicweb.net/Documents/DocumentList.aspx?ID=1606.

the process [and by extension, the visualizations] may have been "preaching to the converted" and that other variables such as political and economic pressure will be more important than the visualizations.

5.5. Actual outcomes in terms of policies and the built environment

Parts of Kimberley's Integrated Community Sustainability Plan or ICSP (Centre for Sustainability Whistler, 2011) were informed by the KCAP. However, no visualizations were included in the ICSP – it still seems unusual to include visualizations in strategic policy documents. Nevertheless, interviewees identified a dozen operational changes, policy changes and built projects that were informed by the adaptation process and visualizations, including that Council decided on a new water conservation scheme, a sprinkler bylaw, and solar lights for the trails. Above all, the first phase of a re-naturalized creek and flood retention zone now mitigates flood risk in the town center, similar to the conceptual green infrastructure design from the visualizations (personal communication, two interviewees, see Figs. 4–6).

Fig. 6. Photo of the first phase of work on the Mark Creek Flume Flood Management and Stream Rehabilitation Project in April 2013 (photo: T. Pollock, 2013).

Other ideas from the KCAP such as a composting facility, solar panels on the roof of the community pool and a biomass facility have continued to be discussed. A solar photovoltaic farm, located on the former mining concentrator site and similar to the one in the visualizations, is now being constructed by a public/private consortium. The private company launched the idea without knowing about the KCAP. Conceptually, however, the ground had been prepared with staff, council and citizens, demonstrating the utility of scenarios that go beyond adaptation to include mitigation solutions.

5.6. Unexpected results: breadth of influence and behavioral change

A surprising finding was the breadth of uses of the visualizations, from fire awareness to green buildings to creek re-naturalization. In hindsight, this should have been expected as the project had linked multiple thematic layers under climate change planning. These have now dis-aggregated back into their "silos." Secondly, one interviewee reported his department had begun carpooling to work. Such individual changes in behavior, more than one year after the KCAP process and Open House, had not been expected.

6. Discussion and conclusions

The key findings from the process evaluation were that the visualization materials, presented through posters, in a slideshow presentation and in a virtual globe, helped to increase participant awareness and understanding of the community's vulnerabilities, climate impacts and response options including land use choices. The Open House increased self-reported concern over local implications of climate change in Kimberley, with some participants stating their intention to take action in response to the information provided. Comparable results have been found in other geographic settings (e.g. Bishop et al., 2013; Cohen et al., 2012, 2013). Follow-up interviews 22 months later confirmed that participants perceived the visualizations to be helpful, and had continued to use them in some settings.

Real-world settings may provide results that laboratory settings can build on for further investigation. For example, virtual globes were ranked highly by only half the respondents, with just under 50% of questionnaire respondents ranking them last in visual media and a small minority of respondents (three out of 38) stating explicitly that they preferred traditional means of communication such as posters. In other words, they explicitly rejected virtual globes and "rapid digital media" as being inaccessible for some participants. Bishop et al. (2013) could not confirm this finding but their sample of participants consisted of experts only. In contrast, interviewee statements from the KCAP process note challenges for "older users," i.e. users who grew up before digital technologies were widespread. Visualization experiments may need to expressly expand participant diversity to a broader set of "publics" beyond expert stakeholders. We suggest further experiments comparing users of different age groups and comparing domain experts to lay people.

6.1. Longitudinal evaluation indicates transformative or incremental change toward a shared goal

Based on multiple evaluation streams, it is clear that change toward climate change planning goals has occurred in Kimberley as a result of the Kimberly Climate Adaptation Project. Awareness increased among decision-makers, stakeholders and citizens, numerous policies and operations have been changed, and specific adaptation and mitigation projects put forward in the KCAP have been built in the following five years, suggesting a transformative change toward planning for climate change. Though it is impossible to directly link the long-term outcomes solely to the visualizations, on the whole, the interviewees agreed that both the visualizations and the broader adaptation planning process supported the changes in the City following the KCAP. The main merit of the visualizations – and the scenarios they depicted – lay in creating and communicating ideas and practical solutions to move toward a more resilient community, thereby adding value to a new adaptation process.

The added value of the visualizations came both from the digital media and the longer-term availability of more traditional media. Similar to findings in Bishop et al. (2013), this study found that the free exploration of the virtual globe tool (multi-dimensional interaction) was appreciated by participants as "helpful" and "adding value" during the process, with the previously discussed caveats. However, traditional presentation formats like posters and reports seemed to be more accessible during the later planning stages than the virtual globe. Galler, Krätzig, Warren-Kretzschmar, and von Haaren (2014) demonstrated similar results for an online survey among planning officials in German landscape and environmental planning: by far the most popular digital presentation format were PDF documents because they are easily accessible and fulfill the same legal requirements as printed documents. This situation may change over time, with increased mainstreaming of the technology and improved Internet access in rural/smaller communities so that more interactive presentation formats may also become more important in the long-term.

6.2. Limitations of the evaluation methods

Unfortunately, the videotaping of virtual globe users did not reveal additional insights on user interactions beyond verbal commentary. That was partly due to ethics because, unlike Gill et al. (2013), we were not allowed to film the person but only the screen. If we had been allowed to film the person as well, gestures and head positions could have also indicated how users interact with the virtual globe.

The retrospective evaluation may be subject to intrinsic biases that can occur with any interview process where the researcher is associated with the earlier process and is known to the interviewee, in terms of a possible tendency to say what they think the researcher wants to hear. Bishop et al. (2013: 231f) suggest the "pooling of results from different research groups" to characterize the issue across studies.

6.3. Visualizations embedded in the process inform change on the ground

Visualizations are only as good as the participatory process in which they are embedded (Lewis, 2012) and therefore, both have to be well integrated in practice (Pond et al., 2010) and examined together. Three types of combined visualization/process outcomes were identified by the interviewees:

- Individual behavioral change, e.g. car pooling or that a former climate skeptic decision-maker started considering the urgency of climate action; no information is available on general change of behavior among the local public.
- Operational, policy and built changes (e.g. the Flood Management and Stream Rehabilitation Project 2012) were informed by the KCAP and its visualizations.
- Local "champions" are driving change in the community using the visualization products.

Again, we cannot attribute these to the visualizations alone, but there is evidence that visualizations contributed to the overall impact of the KCAP, and thus to the outcomes to date. Although the visualization work took place between 2008 and 2009, the virtual globe software has changed surprisingly little, e.g. Bishop et al. (2013) were using the same API. What has changed is the range of display options and controllers, e.g. Gill et al. (2013) test wireless videogame controllers and 3D glasses in addition to traditional displays and the same authors propose mobile devices capable of augmented reality (Gill & Lange, 2013). Based on this study and Bishop et al. (2013), Gill et al. (2013), Lewis (2012) and Pond et al. (2010), we recommend further careful application and testing of virtual globes to enhance public understanding of local climate change risks and future response options, with a focus on how to sustain the communication over time, and the testing of novel display types. Further insights might be provided through a study tracking the continued use of influential scientific and design visualizations in spatial planning and geodesign (Steinitz,

2012) processes, including monitoring the impact of changing digital media technologies over the longer term.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2015.03.011

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Dr. Schroth completed graduate work and his PhD in landscape planning in Europe, focusing on the planning and GIS/geovisualization interface for participatory planning. He joined the University of British Columbia's Collaborative for Advanced Landscape Planning (CALP) in 2008 to lead the development of interactive visualizations for the Kimberley Climate Adaptation Project. In 2012, he started as lecturer in landscape planning and GIS at the Department of Landscape at the University of Sheffield.

Ellen Pond develops leading edge climate change and sustainable energy solutions in collaboration with local governments. In her work at CALP at UBC, Ellen designed and evaluated climate change planning processes with local communities.

Prof. Dr. Sheppard teaches sustainable landscape planning, aesthetics, and visualization in the Faculty of Forestry and Landscape Architecture program at UBC. Current research interests include climate change perceptions and planning, the aesthetics of sustainability, and visualization theory and ethics.