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Citizen-led emissions reduction: Enhancing enjoyment and understanding for diverse citizen engagement with air pollution and climate change decision making

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ABSTRACT

Diverse citizens need to be involved in net zero transitions to ensure policy interventions do not entrench inequalities for people from minoritised or disenfranchised groups and ensure public engagement with rapid social changes. This paper illustrates the importance of designing enjoyable engagement activities aimed at segmented citizen and community groups, to ensure a broad cross-section of society can participate in environmental debate and policymaking. We analysed an evaluation sample of 857 people, representing 10.3% of the 8302 people directly engaged with the ClairCity project from six European countries. Women were under-represented in our activities, and younger participants preferred non-traditional forms of engagement like online games. Across all activities, multiple regression analyses found statistically significant relationships between younger age groups and enjoyment, and a positive correlation between enjoyment and understanding of air quality. Behaviour change intention was also significantly positively correlated to understanding, with 74% of participants indicating they would make a behaviour change to improve air quality. While climate change and air pollution are serious issues, public engagement to raise awareness and improve participation in policymaking does not have to be. To fully realise citizen-led emissions reduction, policymakers need to co-create engagement activities which are enjoyable, inclusive, and attractive to diverse citizens representing regional demographics. Ultimately, the more enjoyable and relevant the engagement activities, the more understanding people gain about the issues, and are therefore more likely to make a change to individual or community behaviours to reduce air pollution and carbon emissions and improve public and environmental health.

1. Introduction

Climate change-induced disasters are now occurring around the world, with the Intergovernmental Panel on Climate Change calling the latest scenarios of global heating 'a code red for humanity' (IPCC, 2021). Action from policymakers is urgently required to reduce greenhouse emissions (IPCC, 2018), with the IPCC and International Energy Agency calling for a rapid transition away from fossil fuel technologies (IEA, 2021), alongside changes in citizen behaviour to reduce demand for energy and transport (IPCC, 2022). This transition to a low/zero carbon economy would also have the concomitant effect of reducing air pollution, which the World Health Organisation (2013) has identified as the biggest environmental risk to public health.

1.1. Citizen involvement in political decision making

The scale of technological and behavioural transformation required to mitigate climate change, necessitates citizen involvement at all levels of political decision making and particularly in co-development of solutions. In this paper, we argue that environmental communications and engagement needs to focus on creating societal change in order to enable individual behaviour change. In other words, people need to be given

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opportunities to change through fair policy interventions which mitigate economic or social issues, they need to see leadership from others role modelling behaviour changes, and they need to be supported in doing so through community asset-building. Building on Collins and Ison (2009), we similarly advocate for social learning approaches to natural resource management, whereby many different groups have a partial understanding of the issue, and public policy engagement should seek to bring these multiple realities together to ensure a fair transition.

Currently, citizens have very few opportunities to engage with decisions around emissions-reduction, despite opinion polls indicating high concern for climate change – for instance a UK Government survey indicated that 85% of the British public are concerned, and 87% support renewable energy action (BEIS, 2021). Drawing on Arnstein's Ladder of Participation (Arnstein, 1969), this would indicate that citizen participation in neoliberal politics is limited to the lower limits of 'non-participation' or 'degrees of tokenism', where participatory exercises are used to inform, consult or placate citizens (Arnstein, 1969). Power in local or national decision making is still generally not redistributed into partnership, delegated control, or even citizen control (Arnstein, 1969), and instead citizens tend to be engaged merely to legitimise or show support for top-down decision making, rather than co-developing solutions together at the start.

In parallel, science communication and public engagement efforts for air pollution tend to focus on individuals (Riley et al., 2021), communicating the impact of our personal behaviours in the hope we change to benefit the environment or other citizens. However, psychological and social research indicates that asking individuals to change their behaviour against the norms of society is at best ineffective, and at worst harmful to the individual (Chatterton, 2017). Social Cognitive Theory indicates that parts of an individual's learning can be directly related to observing others within the context of social interactions and outside media influences (Bandura, 1977, 2001). Similarly, the COM-B model of behaviour change (Michie et al., 2011) recognises that an individual's behaviour is part of an interacting system of their capability, opportunity, motivation and behaviours. Indeed, many determinants of behaviour lie outside the individual, and to this end Chatterton and Wilson (2014) developed the "Four Dimensions of Behaviour" framework in order to highlight how diverse 'behaviours' can be, and how they can range from ones dominated by internal cognitive processes to ones which are constrained by physical or social systems and structures. Citizen engagement is therefore important to empower communities to co-design systemic solutions which enable opportunities for change while mitigating financial or social penalties for individuals.

To fully understand the norms and barriers to changing societal behaviours within diverse cultural groups and communities, policymakers need to harness social learning. Collins and Ison (2009) define this as building relational capital to agree shared purpose, co-creating knowledge of the problems, and negotiating concerted action for societal behaviour change. Reflective of Arnstein's call for more citizen power (1969), there is a growing recognition within the climate movement for shared power, with activists acknowledging intersectional issues and advocating for climate justice for minoritised groups and indigenous campaigners (Friends of the Earth, 2022). Similarly, climate communications researchers advocate for collaborative and trans-disciplinary projects bringing together the social and physical sciences alongside artists and communication practitioners (Moser, 2016). Collaborative, creative, and enjoyable approaches to social learning mean citizens can learn from each other and negotiate shared solutions reflective of different social identities and values (Collins and Ison, 2009). This paper explores a suite of engagement approaches which aim to enable participation in climate and air pollution decision making, alongside developing new approaches to bottom-up co-development of rapid policy transition.

1.2. *ClairCity project – citizen-led air pollution reduction in cities*

Public engagement and behaviour change theories were put into practice in the EU ClairCity project (Fogg-Rogers et al., 2021) (Ref No: 689289), which ran from 2016–2020. The project sought to understand the role of citizens' day-to-day behaviours, practices and activities and the perceptions of those activities in the generation of air pollution and carbon emissions. The project focussed on six case study cities and regions: Amsterdam in the Netherlands, the Aveiro region of Portugal, Bristol in the U.K., Ljubljana in Slovenia, the Liguria region of Italy, and Sosnowiec in Poland. The cities/regions are all small-medium sized with over 50,000 residents and were chosen to reflect differing political and behaviour scenarios.

Using a sociologically informed perspective, the inter-disciplinary project aimed to shift the policy focus from technology and technological solutions to the problems caused by people's daily practices, activities and behaviours and the negotiated shared lived reality (see Fig. 1 for a graphical abstract). Modelling was conducted to assess the baseline status of air quality, carbon emissions and related public health in the case study cities (Fogg-Rogers et al., 2021) and the policy landscape for each city region was also assessed, to understand the current interventions applied to reduce emissions (Prestwood et al., 2017; Slingerland and Artola, 2020b).

The second phase of the project aimed to crowd-source novel policy interventions, as well assess acceptability of potential policy interventions with different demographics. Core to the project were a set of engagement tools that were designed for city residents to participate in understanding the problem, visioning the future and taking shared ownership of the solutions to achieve results for their city region (Sardo et al., 2020). The engagement activities were designed in accordance with science communication literature and practice (Fogg-Rogers et al., 2019; Fogg-Rogers and Boushel, 2017; Gilbert, 2010), but were adapted for recruitment and delivery purposes to suit the different country and city demographics and political landscape. The resulting crowd-sourced policies focussed on transport and heating emissions and sought to provide solutions to the social and structural organisation of each city to ensure that low emission options could become embedded in citizens' everyday lives.

Public engagement was embedded throughout the project, and this paper will explore the effectiveness of the activities to encourage citizen involvement in policymaking. The overall aim was to raise awareness of air pollution and climate change along with the policies needed to reduce emissions. The evaluation of outcomes therefore sought to assess citizen learning; a broad concept outlined in the 'Generic Learning Outcomes' encompassing attitudes and values, enjoyment, knowledge and understanding, skills, and behaviour (Museums Libraries and Archives Council, 2014).

This paper presents the evaluation of the public engagement activities, and our research questions were:

1) Which audiences engaged in each activity and how did they differ?
2) How much did the project change understanding and behaviour around air pollution and carbon emissions?
3) Are people who engaged in the ClairCity public engagement activities now planning to change their behaviour?

2. Materials and methods

A variety of engagement and evaluation methods were used throughout the project, and these are outlined in this section. Full ethics approvals were achieved for all elements of the project from the UWE Bristol Research Ethics Committee, with replicated processes applied throughout the partner countries. Each case study partner was responsible for deploying the engagement methods in their national languages, using varying recruitment methods adapted for the country situation and described in the full ClairCity Evaluation Report (Sardo et al., 2020).

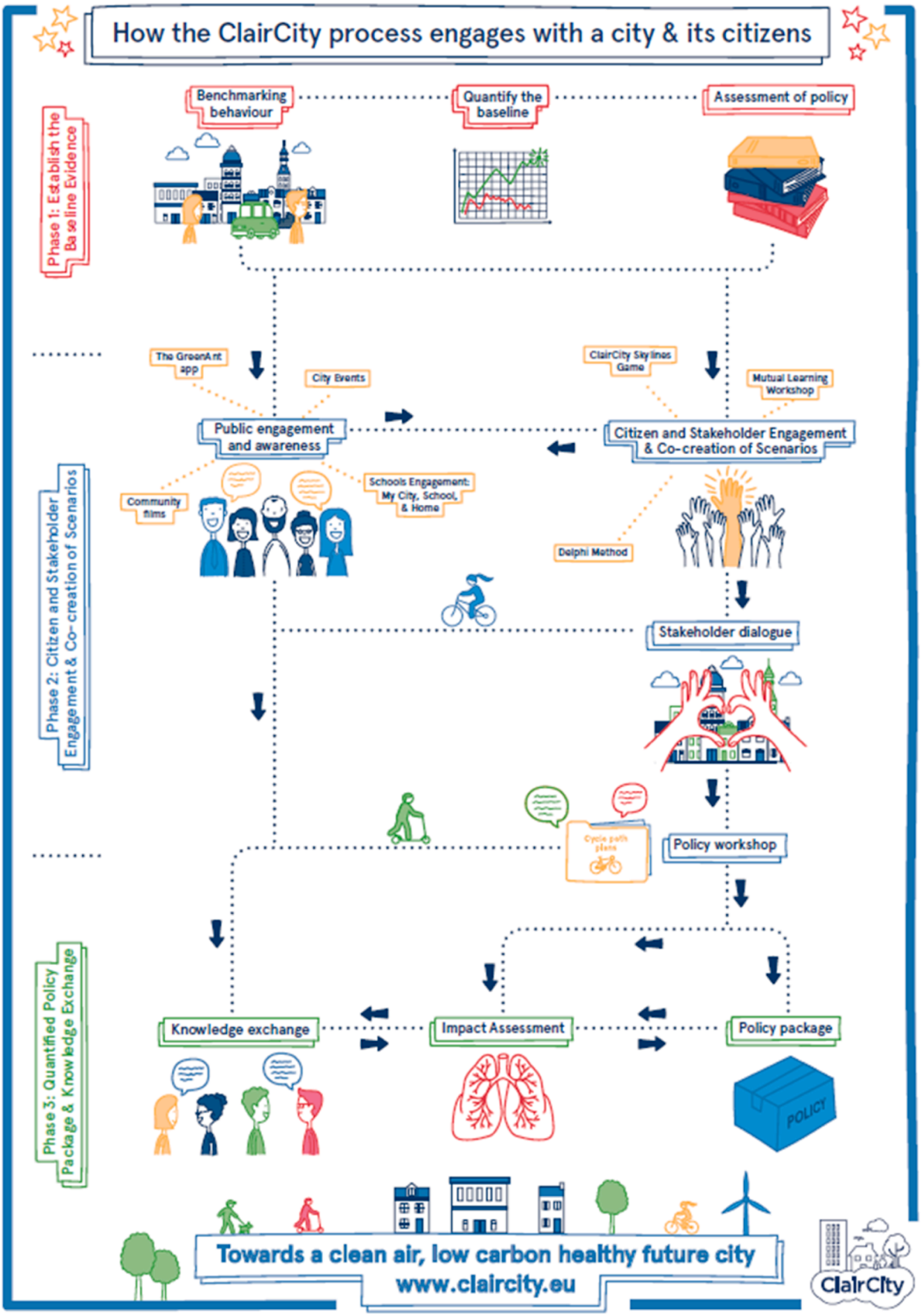


Fig. 1. The ClairCity project process.

All citizens gave informed consent before participating in the engagement activities and were subsequently asked to provide informed consent for the evaluation of the activities as well. The evaluation methodology was designed to collect high quality data in a straightforward way that worked across all partners, languages and cities.

2.1. Engagement methods

The following engagement methods were deployed in each of the six city regions and are described below (and illustrated in Fig. 1).

- Skylines Game (King et al., 2019): a mobile phone 'serious game' designed to crowd-source public perceptions and public acceptability of different policy interventions, where participants were encouraged to balance different policies by acting as Mayor of the city.
- App (Fredriksen et al., 2019): a mobile phone app named 'Green Ants', which aimed to enable citizens to monitor their transport activities, emission generation, and pollution exposure using mobile GPS data. The app was only piloted with project supporters, as part of basic validation processes during development.
- School Competition (Szuppinger et al., 2021): My City, My School, My Home engaged young people (below aged 18) in a competition to select interventions they preferred to reduce emissions from housing, transport, and use of resources.
- My City Videos (Csobod et al., 2019): Older adults were invited to make films about the changes in their city, their personal mobility and the steps they take to minimise their exposure.
- Citizen Delphi process (Barnes and Csobod, 2018): iterative surveys and workshops were employed to recruit citizens as local experts in their cities. A mixed method survey generated qualitative examples of lived experiences and potential policy ideas, which were then voted on in a subsequent quantitative survey, and then discussed in diverse geographic and demographic community qualitative workshops around each city.
- Workshops:

  - Mutual Learning Workshop (MLW) (Csobod and Buddies, 2018): citizens were brought together with informed stakeholders with backgrounds in air pollution, carbon emissions, and health and wellbeing, to discuss the challenges facing the city and then co-create policy interventions for cleaner, healthier futures.
  - Stakeholder Dialogue Workshop (Barnes, 2019): citizens and stakeholders were brought back together to review and discuss the Delphi outcomes, Mutual Learning Workshop and ClairCity Skylines evidence and co-create scenarios for low carbon, clean air, healthy futures.
  - Policy Workshop (Artola and Slingerland, 2019): The scenarios generated in the Stakeholder Dialogue Workshop were quantified and then returned to the local stakeholders to agree a single Unified Policy Scenario.

2.2. Evaluation methods

The evaluation design was cross-sectional post-intervention, with all participants invited to take the anonymous surveys but completion was voluntary. All activities were evaluated with quantitative surveys which were either delivered as online surveys emailed post-event (using Bristol Online Surveys), pop-up surveys coded into the app/game, or paper surveys returned in person at events. The surveys were tailored for each format and city, aiming to address the research questions outlined in Section 1.2 (full surveys can be viewed in the ClairCity Evaluation Report (Sardo et al., 2020)). The questions gathered data, where appropriate, on participant age, gender, and education level/expertise; ethnicity was also collected in Bristol, UK, but not included elsewhere as several European countries indicated this was not appropriate in their local context. The questions also assessed learning from the activities, including changes to enjoyment, understanding, and intended behaviour. Table 1 indicates the engagement activities, intended audiences, and evaluation methods. Table 2 indicates how the constructs were assessed across the different surveys.

Survey design varied depending on the intended dwell time of the engagement activities, and the intended age and education level of the participants. The online questionnaires and pop-up windows with questions were designed to be quick and easy to complete, with mainly closed quantitative questions, as this assisted in making translation and data analysis straightforward. Open-ended qualitative questions were also included to enable participants to explain their answers but were kept to a minimum as they tend to have a lower response rate in public engagement evaluations (Grand and Sardo, 2017; Sardo and Grand, 2016).

2.3. Survey analysis

Both online and paper questionnaires were translated and distributed to participants in their national languages, with answers translated back to English for analysis by the project researchers. Online surveys and pop-up mini surveys were downloaded into an Excel sheet (Microsoft 365) for analysis and translated to English where needed. Paper surveys were transcribed into the Excel sheet and also translated to English. The original national language responses were kept securely in the case study countries, to ensure data protection for participants. The anonymised data sheets were transferred to the UK for overall compiled analysis (and kept in an online secure storage in accordance with the General Data Protection Regulation), with data standardised and cleaned for descriptive analysis using Excel.

Descriptive and analytical statistics were conducted using SPSS (V26 and V29). Participant demographics were analysed descriptively to compare age, gender, education and expertise level per activity and per city. Multiple Regression Analyses were conducted to assess relationships between demographics and activity ratings for enjoyment or understanding. Further non-parametric Chi-Squared and Spearman Correlation analytical statistics were conducted for categorical and nominal data to determine demographic differences and behaviour change intentions.

Table 1
Evaluation methods per engagement activity.

Engagement method and recruitment	Intended audience	Evaluation method	Topics assessed
Delphi process – advertisement and self-selection, some targeted recruitment	Ordinary citizens (over 18) Expert Stakeholders	Online survey	Age, Gender, Education, Enjoyment, Understanding, Behaviour
Skylines Game – advertisement and self-selection	Young people (aged 13-17) Ordinary citizens (over 18)	Pop-up mini survey	Age, Gender, Expertise, Enjoyment, Understanding, Behaviour
App – targeted recruitment	Ordinary citizens (over 18)	Pop-up mini survey	Enjoyment, Understanding, Behaviour
Schools Competition – targeted recruitment	Young people (aged 13-17) Teachers	Online survey for teachers	Age, Enjoyment, Behaviour
My City Videos – targeted recruitment	Older adults (over 60)	Online survey	Age, Gender, Enjoyment
Workshops – advertisement and self-selection, some targeted recruitment	Ordinary citizens (over 18) Expert Stakeholders	Paper and online survey	Age, Gender, Education, Enjoyment, Understanding, Behaviour

Table 2
Survey questions used to assess each construct.

Construct	Data collected	Engagement method	Justification
Age	Multiple choice ordinal age categories: 13-15; 16-24; 25-34; 35-44; 45-54; 55-64; 65 +	Delphi process Skylines Game Workshops My City videos	It was important to understand which engagement options appeal to different age groups. The app was only tested by project supporters, and so age and gender were not collected.
Gender	Multiple choice categories: Male; Female; Prefer not to say	Delphi process Skylines Game Workshops My City videos	It was important to understand which engagement options appeal to different genders. The gender of teachers in the school competition was not relevant as they were by-proxy reporting for children. The app was only tested by project supporters, and so age and gender were not collected.
Education level	Multiple choice categories: Secondary Education; Vocational Qualification; Bachelor Degree; Postgraduate Education;	Delphi process Workshops	Education level was collected in the more formal workshop activities, where providing an education level was deemed to not be disruptive to the tone of the activity, and was also necessary to determine participants' prior education for evaluation of engagement.
Expertise	Slider Likert scale (1-5) embedded in the Game asked participants for their expertise in air pollution and carbon emissions before playing, where 1 is 'Novice' and 5 is 'Expert'.	Skylines Game	The survey was embedded within the game and needed to follow the style of the 'serious game'. Therefore, 'expertise' was chosen over education level, as it implied a gaming characteristic of self-declared prowess. The expertise topic was air pollution and carbon emissions.
Enjoyment	Likert scale (1-5) asking how much participants enjoyed the activity, where 1 is 'I Hated it', and 5 is 'I Really enjoyed it'.	Delphi process Skylines Game App Schools competition My City videos	Enjoyment is a key criterion for learning and engagement, which we assessed in most activities. We did not ask people in the stakeholder and policy workshops if they enjoyed the activities, as they were designed to be serious policy dialogue sessions.
Understanding	Likert scale (1-5) asking how much participants rated their understanding following the activity, where 1 is 'I'm much more confused', and 5 is 'I know a lot more'.	Delphi process Skylines Game App Stakeholder Workshops	Understanding was evaluated in the engagement activities with more instructive aspects, where some information was imparted during the activity.
Behaviour	A multiple-choice question asked whether participants will change their behaviour following the activity (individual or societal) with no/maybe/yes options. A follow-up qualitative question was included so participants could elaborate their reasons.	Delphi process Skylines Game App Schools competition Workshops	Behaviour change potential was evaluated in engagement activities where participants had viewed or discussed potential emissions-reductions options, to assess whether individuals would personally act on the changes suggested.

3. Results

A total of 8302 people from the six cities/regions took part in the engagement activities during the project. Evaluation participants self-selected from the people partaking in the engagement activities, resulting in N=857 people completing evaluation surveys across seven activities held in six cities/regions (plus a worldwide option for the game). This gives an evaluation sample size of 857 survey evaluators from 8302 participants, giving a 10.3% return rate, which is similar to previous literature (Funkhouser et al., 2014; Grand and Sardo, 2017).

There was substantial variation between cities in the activities and evaluation return rate. The project design selected diverse case study cities/regions, recognising that some activities will appeal more to different populations. The cities which recruited the most evaluation participants were Sosnowiec (N=353) and Aveiro (N=137), due to high promotion through the city/region official council communication channels. The total engagement and evaluation numbers for each city and activity are visualised in Fig. 2.

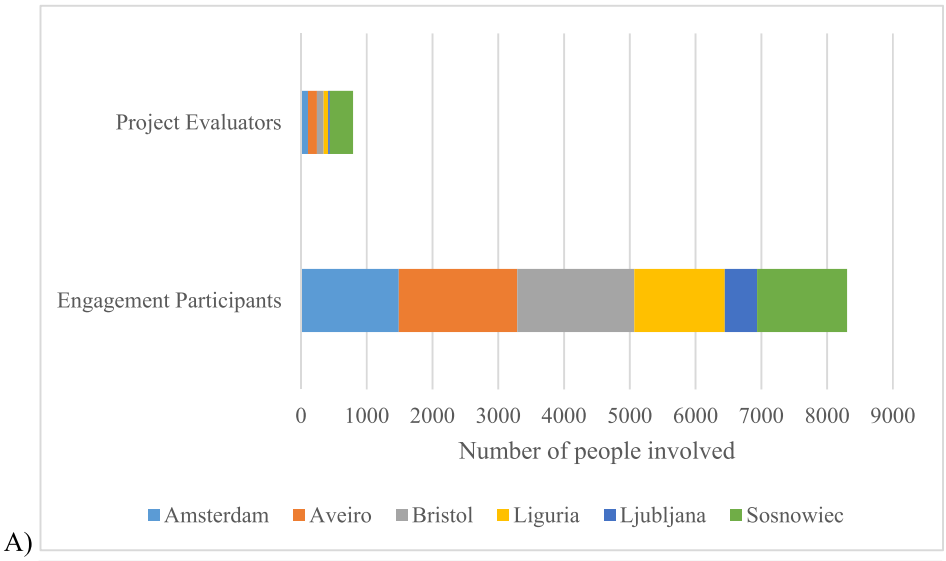
The data presented in the following sections analyses participant responses in the evaluation surveys, which we will differentiate as 'evaluators' (N=857) as compared to overall engagement participants.

3.1. Overall evaluation demographics

Evaluators for most activities were fairly evenly split between male and female participants, with the exceptions being the Policy and Stakeholder workshops (attracting more senior members of organisations, who tended to be men) and the Skylines Game. The activity which collected the most evaluation reports was the game (N=560); this high level of male players has meant that the overall evaluation gender ratio is skewed towards men (see Table 3). In total, 281 females (37.5%) participated in the evaluation, compared to 469 males (62.5%).

Ethnicity was only recorded in Bristol, with 7% of participants identifying as from Black, Asian and Minority Ethnic backgrounds, compared to 15% of the overall city population; this was despite purposive sampling in areas with diverse populations (Barnes and Boushel, 2018). Similar data was not collected for other countries.

Overall, the mode age category was 16–24 year olds, encompassing 28% of evaluators, due to high participation in the game. Cities which recruited a higher number of game players tended to have younger evaluation participants. However, overall, all age categories were represented due to different engagement activities appealing to different ages of people, as well as purposive selection to some activities. For instance, the workshop activities were targeted towards organisational experts, and reached 77% of people in the age category of 55–64 year olds and 100% of 65 + year olds (see Table 3).



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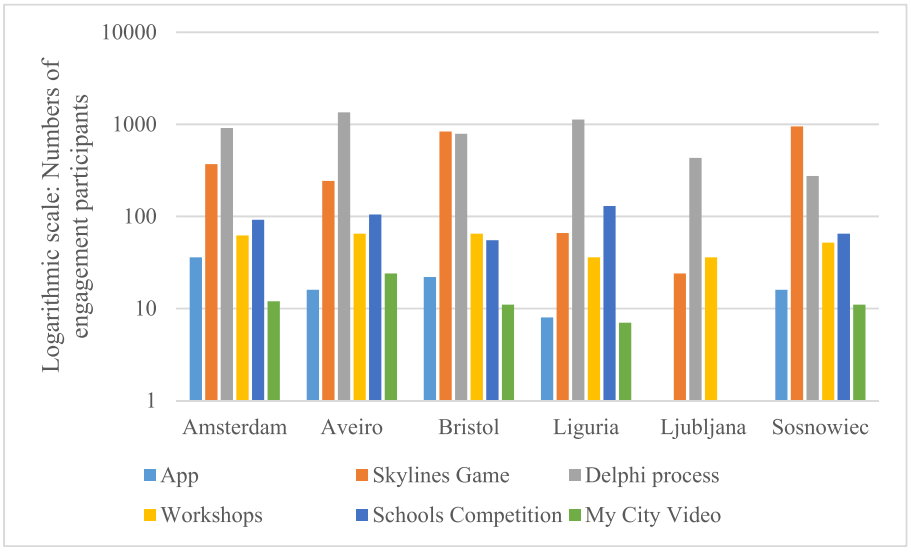

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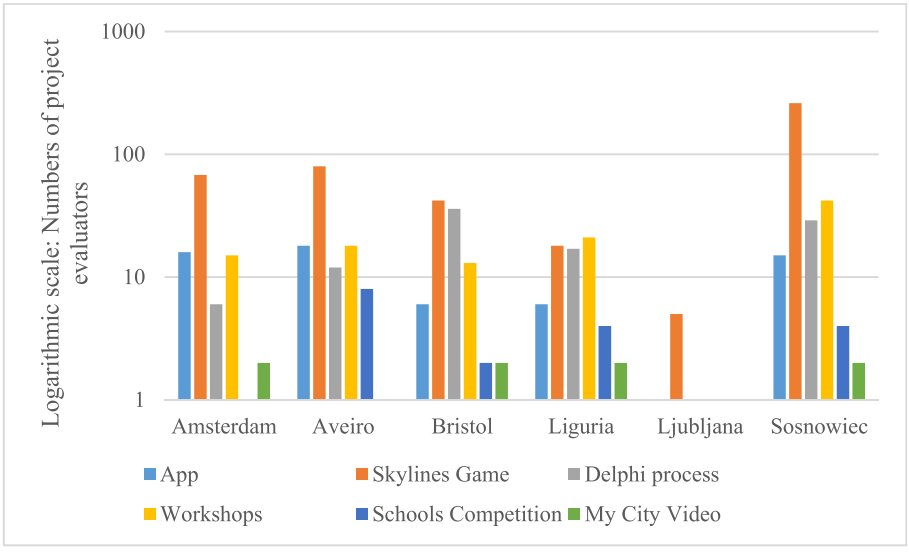

C)

Fig. 2. Graph A shows total engagement across all cities/regions, alongside evaluation sample size. Graph B shows the comparison between recruitment to different engagement activities in each city/region (please note logarithmic scale). Graph C shows varied evaluation samples for each activity and city due to evaluators self-selecting (please note logarithmic scale).

Table 3
Evaluation data comparing demographic characteristics and ratings of activities.

Count of Evaluators	Activity	App	Skylines Game	Delphi process	Policy Workshop	Stakeholder Workshop	Schools	Video	Totals
City	Amsterdam	16	68	6	3	12	0	2	107
	Aveiro	18	80	12	6	12	8	1	137
	Bristol	6	42	36	0	13	2	2	101
	Liguria	6	18	17	16	5	4	2	68
	Ljubljana	0	5	0	0	0	0	0	5
	Sosnowiec	15	261	29	19	23	4	2	353
	Worldwide	-	86	-	-	-	-	-	86
Total		**61**	**560**	**100**	**44**	**65**	**18**	**9**	**857**
Gender	Female	-	176	51	21	27	-	6	281
	Male	-	358	48	23	36	-	4	469
Total		**-**	**534**	**99**	**44**	**63**	**-**	**10**	**750**
Age (years)	13-15	-	72	0	0	0	0	0	72
	16-24	-	197	12	0	2	0	1	212
	25-34	-	140	12	4	4	4	2	166
	35-44	-	120	16	8	20	8	2	174
	45-54	-	25	32	5	25	5	2	94
	55-64	-	6	20	0	7	0	2	35
	65 +	-	0	5	0	4	0	0	9
Total		**-**	**560**	**97**	**17**	**62**	**17**	**9**	**762**
Education	Secondary	-	-	21	2	3	-	-	26
	Technical	-	-	2	1	8	-	-	11
	Bachelors	-	-	36	12	32	-	-	80
	Postgraduate	-	-	40	21	18	-	-	79
Total		**-**	**-**	**99**	**36**	**61**	**-**	**-**	**196**
Expertise	1 = Novice	-	134	-	-	-	-	-	134
	2	-	124	-	-	-	-	-	124
	3	-	195	-	-	-	-	-	195
	4	-	77	-	-	-	-	-	77
	5 =Expert	-	30	-	-	-	-	-	30
Total		-	**560**	**-**	-	-	**-**	-	**560**
Enjoyment	1 =Hated it	9	13	0	-	-	1	0	23
	2	24	43	0	-	-	4	0	71
	3	11	198	9	-	-	1	1	220
	4	1	132	45	-	-	4	6	188
	5 =Really enjoyed it	0	174	46	-	-	6	3	229
Total		**45**	**560**	**100**	**-**	**-**	**16**	**10**	**731**
Understanding	1 =Much more confused	8	38	0	-	0	-	-	46
	2	14	57	0	-	2	-	-	73
	3	24	250	12	-	1	-	-	287
	4	8	115	62	-	9	-	-	194
	5 =Know much more	2	100	26	-	5	-	-	133
Total		**56**	**560**	**100**	**-**	**17**	**-**	**-**	**733**
Behaviour change intention	No	34	110	10	-	2	5	-	161
	Maybe	0	0	26	-	6	1	-	33
	Yes	19	450	50	-	30	12	-	561
Total		**53**	**560**	**86**	**-**	**38**	**18**	**-**	**755**

Note: Data represents the count for each evaluator response. Not all evaluators completed all the demographic questions as part of their survey completion. This means that the totals for each category do not add up to the total number of evaluators. Constructs were assessed per activity as described in Table 2; absence of data is indicated with a hyphen.

3.2. Expertise and education level

Evaluators in the Delphi, Policy and Stakeholder workshop evaluations (N=209) were asked their education level (in prior coded categories). Workshop evaluators were overall very highly educated, with 81% holding a Bachelor's or Postgraduate degree. While education levels vary in each country, this compares to 47% of the UK population with a National Qualification Framework (NQF) Level 4 (e.g. Certificate of Higher Education) or higher qualification (Office for National Statistics, 2022).

Evaluators in the Skylines Game (N=560) were asked their self-rated expertise about air quality and carbon emissions on a scale of 1–5, where 1 was no knowledge (novice), and 5 was expert level. The mean expertise value was 1.6 out of 5 (SD=1.8), indicating that game evaluators felt they had little prior knowledge about air pollution, carbon emissions or health consequences, with only 19% of game evaluators rating themselves as being well informed or having expert knowledge.

The cities varied in the expertise and education level of the participants they recruited to participate in the activity evaluations. A Chi-Squared Test of Independence showed there were statistically significant differences between the education levels of evaluators in the different cities [X^2 (12, N=196) = 39.06, $p < .001$] and the expertise levels for evaluators in the different cities [X^2 (24, N=577) = 66.18, $p < .001$]. Bristol and Sosnowiec recruited the highest proportion of evaluation participants with no knowledge or little knowledge of air pollution and carbon emissions (low expertise), due to high engagement in the Game. Amsterdam recruited proportionally more people from a postgraduate education background than other cities, and Sosnowiec recruited proportionally more people with solely secondary education.

A greater proportion of female evaluators held a postgraduate degree (53% female; 47% male), although more men held a Bachelor's degree (38% female; 63% male). This is comparable to UK statistics on education levels, with 49% of females holding a NQF Level 4 or higher qualification, compared to 45% of males (Office for National Statistics, 2022). However, a Chi-Squared Test of Independence showed that this trend was not statistically significant in our evaluation sample [X^2 (3,

N = 195) = 6.01, p = .111].

3.3. Learning outcomes from engagement activities

3.3.1. Enjoyment

Enjoyment was rated by *N*=731 evaluators and the mean value was 3.7 out of 5 (*SD*=1.1), where 5 represented 'I really enjoyed it', indicating that there was a reasonably high level of enjoyment. The activities which achieved the highest enjoyment scores were the Delphi workshops and Videos, with 91% and 90% (respectively) of evaluators either enjoying or really enjoying the activity. Of the Game evaluators, 55% indicated that they enjoyed or really enjoyed the activity. The GreenAnts app was the least liked by its evaluators, with 53% of participants indicating that they disliked it.

A Multiple Regression Analysis was conducted to test if Age, Gender, Education or Understanding predicted Enjoyment levels. The overall regression was statistically significant (R^2 =.227, F(4,91) = 6.663, p < .001). There were no statistically significant differences in the enjoyment levels between men and women. It was found that Age significantly predicted Enjoyment (β = −.347, p < .001) as well as Understanding (β = .222, p = .021). Examination of cross-tabulations found a negative relationship for age i.e. the younger the participants, the more likely they were to say that they enjoyed the activity. There was a positive relationship between enjoyment and understanding (Fig. 4 and). This may be related to the activities younger people tended to take part in, such as the game, or may relate to the enjoyment of learning new information.

3.3.2. Understanding of air quality

The GreenAnts app, Skylines Game, Delphi, and Stakeholder Workshop evaluators (*N*=733) were asked if their understanding of air quality and carbon emissions had changed after participating in the activity. The mean score was 3.4 out of 5 (*SD*=1.1), where 5 was 'I know a lot more now', which indicates that they felt their knowledge had slightly increased. This was influenced by large numbers of game evaluators rating their understanding as staying the same (rating 3) (45%), with most coming into the Game with little expertise in air quality. The Delphi process (*N*=100) was rated the most highly for improving understanding of air quality, with 86% of participants rating the outcome as 'a bit more' (4) or 'a lot more' (5) understanding, and none rating themselves as being more confused (Fig. 3).

There were no statistically significant differences in how men and women or different education levels rated each activity for understanding. However, a Chi-Squared Test of Independence showed there were statistically significant differences between how different age groups rated their understanding following ClairCity activities [X^2 (20, N = 674) = 73.64, p < .001], with younger evaluators tending to rate their understanding as staying the same, whereas older people tended to indicate that now they understood more (Fig. 3). This may link to younger participants taking part in the Game, whereas older people tended to participate in the more informative workshops or Delphi process.

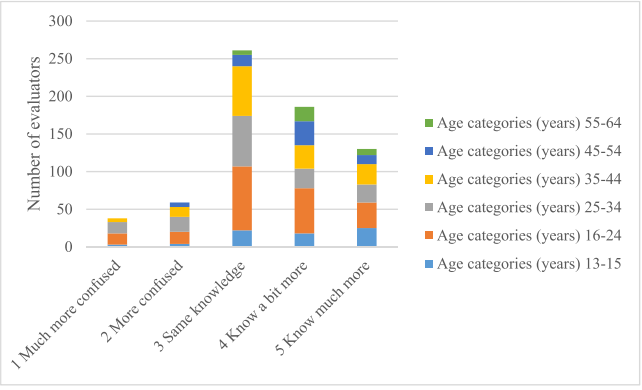

Fig. 3. Comparison of understanding self-reported by evaluators following the engagement activities across different age groups.

A Multiple Regression Analysis was conducted to test if Age, Gender, Education, or Enjoyment predicted Understanding levels. The overall regression was statistically significant (R^2 =.105, F(4,91) = 2.656, p = .038). Gender, Education, and Age (in this test) were not statistically significant. It was found that Enjoyment significantly predicted Understanding (β = .257, p = .021) with a positive relationship; this may mean that the more participants enjoyed the activity they took part in, the more they reported that their understanding of air quality had improved, or equally, the more participants learnt from the activity, the more they reported enjoying it. These results can be seen in Figs. 4 and 5, which compares enjoyment and understanding for three activities.

3.3.3. Behaviour

Where relevant, evaluators were asked if they would do anything differently to reduce emissions after participating in the activities, with the option to choose from 'no', 'maybe', and 'yes'. Overall, 74% of 755 evaluators answering this question said that they would make a change. The Stakeholder workshop and the Game had the most impact on evaluators, with 79% and 80% (respectively) of people indicating 'yes', they would make a change (Table 3).

The areas with the highest percentage of people who said they would make changes were Aveiro and Ljubljana, while the lowest intention ratio was in Amsterdam (but still positive with 59% of evaluators indicting they would change their behaviour); see Fig. 6 for more detail. A Chi-Squared Test of Independence was performed to test the relationship between cities and behaviour change intent following the engagement activities, and this showed statistically significant differences between cities [X^2 (12, N = 753) = 43.32, p < .001]. This may be because people in Amsterdam are already living relatively low impact lives and feel they have fewer changes to make to reduce emissions.

There were no statistically significant differences in how men and women rated each activity for behaviour change. However, a Chi-Squared Test of Independence showed there were statistically significant differences between how different age groups rated their intentions to change their behaviour following ClairCity activities [X^2 (10, N = 700) = 77.45, p < .001]. Cross-tabulation indicated that young people (13–15 and 16–24 years) and older people (54–64 years) had a higher proportion of yes answers (higher intentions to change), with the lowest proportion being in the 25–34 year old age bracket (Fig. 6). This may be related to the perceived capacity or willingness people have to take action at different life stages. In open qualitative questions, 82 participants indicated the actions they intended to take to change their behaviour (Table 4).

A Spearman correlation coefficient was computed to assess the relationship between participants' education level and their behaviour change intention ratio (yes/no answers). There was a negative correlation between the two variables [rs(123) = −.253, p = .005] i.e. the less educated the participants, the more likely they were to say they were going to change their behaviour. This may, however, be a factor of age as previously noted, as fewer older people have been to university and younger participants have not yet had the opportunity.

A Spearman correlation coefficient was computed to assess the relationship between participants' understanding of air quality following the activities and their intentions to change their behaviour. There was a positive correlation between the two variables [rs(716) = .401, p < .001] i.e. the more participants reported that their understanding had improved, the more likely they were to say they were going to change their behaviour.

4. Discussion and conclusions

Improving public engagement around climate change is essential to

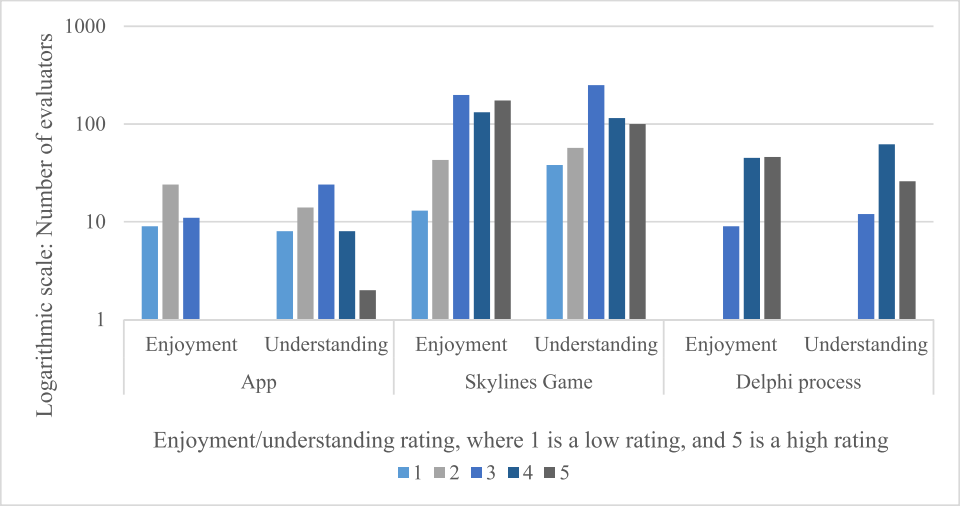

Fig. 4. Comparison of enjoyment and understanding as rated by evaluators across different engagement activities.

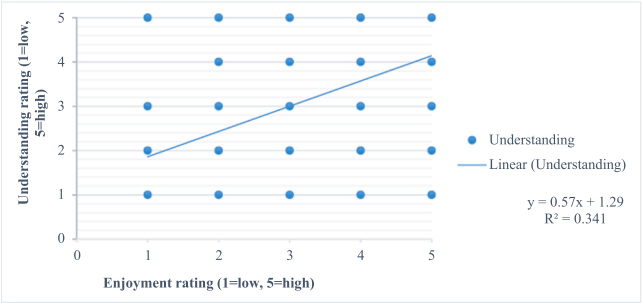

Fig. 5. Scatter plot showing relationship between enjoyment and understanding.

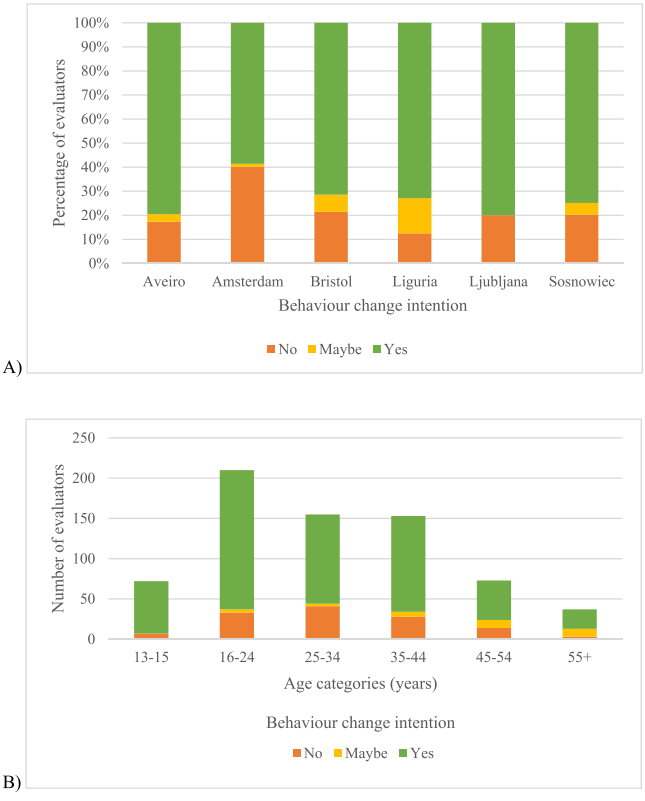

Fig. 6. Comparison between behaviour change intention in each city (Graph A) and different age groups (Graph B), following engagement activities.

raise awareness of health and social impacts, as well as co-designing fair policy solutions to enable rapid transition to zero carbon economies. This paper presents evidence that while different engagement activities appeal to different audiences, no matter which activity people participated in, the more people reported enjoying the activity, they more they also reported understanding the need for emissions reduction, and the more likely they were to pledge to change their behaviours individually or as part of a community. The full spectrum of public engagement therefore needs to be enhanced (Stuart, 2017) via activities tailored to different audiences; from communicating the health impacts of air pollution and carbon emissions, consulting about new technologies or behavioural interventions, involving citizens in the design of interventions, collaborating to enact the changes, and finally empowering communities to make a difference themselves. Policymakers thus play a key role to enable social learning between groups (Collins and Ison, 2009). By designing engagement activities which appeal to different demographics, decision-makers can triangulate engagement data to co-create knowledge of the problems, build relational capital to agree shared purpose, and negotiate concerted action to reduce emissions while mitigating for environmental and socio-economic impacts.

4.1. *Designing public engagement for diverse audiences*

This paper shows the importance of designing a variety of public engagement activities aimed at segmented audience groups, to ensure that a broad cross-section of society can participate in and enjoy engagement with policymaking. The study draws on a large evaluation sample of 857 people, representing 10.3% of the 8302 people directly engaged with the ClairCity project. Within this sample, there were clear differences in the types of audience attracted to each public engagement activity.

More males (N=469, 63%) than females participated in the evaluation due to the most popular engagement activity being the Skylines Game, with a high level of male players. Similarly, the workshops also reached more male participants, as they were recruited as expert participants from their organisation (reflecting gender inequity in management positions). This is a limitation with our study - while there were no statistically significant differences in the learning gained for men or women, decision making would be more inclusive if women were purposively recruited to voice their opinions and preferences. Previous

Table 4
Responses from evaluators to open question around behaviour change intent.

Behaviour change intention	Content Analysis Codes	Number of responses	Example quote
Yes	Using the car less or switching to a less polluting car	26	"Use my car less often. Use trains more often".
	Feeding into policy or research	16	"I want to feed more of those ideas into the Bristol Clean Air Zone proposals so they are ambitious and effective".
	Taking active travel or public transport.	18	"Walk whenever possible". "Cycle, walk more"
	Involving others and raising awareness	8	"Help lead a local clean air campaign".
No	Cannot do any more within current situation	7	"There is very little impact I can make as I have no public transport option to get to work and most of my other journeys are walking".
	Already taking action	4	"I will continue to keep car use to a minimum".
	Can't make change alone and need government support	3	"I think this is an issue with our newly elected MP and I will continue to raise the issue at meetings".

research has found that the transport industry across Europe is dominated by male experience (Badstuber, 2019), while men drive more often and further than women in the UK (Department for Transport, 2018). Men tend to also cycle more in the UK (Office for National Statistics, 2018; Stredwick, 2017), although this is not the case in countries where there is extensive cycling infrastructure, such as the Netherlands or Denmark (Pucher et al., 2008). In contrast, more pedestrians and bus users are women (Department for Transport, 2020), and have different travel habits (Dobbs, 2007; Simićević et al., 2016) involving trip chaining or suburb connections, rather than direct commuting patterns (Havet et al., 2021; Turner and Grieco, 2000). More attention is therefore needed to ensure that women are represented in policymaking around air pollution and carbon emissions, to mitigate unintended consequences from male-biased decision making.

Policymakers should ensure that women are either directly recruited into stakeholder meetings and workshops, or that interventions are designed to appeal to women. In the ClairCity evaluation, the Skylines Game had the lowest proportion of women participants (33%), which reinforces previous research about the gender skew and perceptions of males in global gaming (Finances Online, 2022; Paaßen et al., 2017). The women who did participate in the 'expert' forums of the Workshops tended to hold postgraduate degrees, which reinforces research into male-dominated fields indicating women obtain higher rates of postgraduate qualifications (Sishchuk et al., 2020). The activities which did reach more women were the Delphi process of questionnaires and dispersed community workshops, and the schools and video activities. These activities were targeted at specific communities and advertised in community forums and social media, which may enable broader appeal to women. This also may reflect research showing that women tend to have higher environmental concern and pro-environmental behaviours than men (Desrochers and Zelenski, 2022; McCright, 2010; McCright and Sundström, 2013), but time and social constraints mean this concern tends to be channelled into more local or community focussed activism (Alavi, 2020; Noth and Tonzer, 2022). Interventions should therefore be designed to focus on community groups which include more women, to enable equitable and inclusive participation in city or regional-level decision making.

While most activities were openly recruited using the same channels (social media, website, newsletters (Sardo et al., 2020)), the activities recruited very different sub-groups of participants. The Skylines Game was useful to reach a younger audience for engagement, who may not have otherwise engaged with policymaking about air pollution and carbon emissions. Indeed, 28% (N=212) of evaluators were aged 16–25 years old, and concurrently the levels of expertise cited were low, with a mean figure of 1.6 out of 5. This indicates the value of using online engagement platforms and 'serious games' to reach audiences who are not aware of issues around climate change or air pollution, and who do not engage in traditional engagement methods such as questionnaires or workshops. Policymakers could consider similar serious games to crowd-source policies or assess the popularity of different interventions (Fernández Galeote et al., 2022), while being aware of the gender perception biases in gaming (Paaßen et al., 2017). Conversely, the workshop activities tended to attract older participants, reaching 77% of evaluators in the age category of 55–64 year olds and 100% of 65 + year old evaluators. The Policy and Stakeholder workshops were purposively recruited from organisational experts (who tend to be older), but the Delphi workshops had open citizen recruitment. Workshops are a traditional method to enable citizens to engage in decision making, but policymakers need to be aware that they attract older, more educated, and more literate/engaged citizens.

While the video activities were aimed at older people, they required targeted recruitment and staff support to enable older people to engage. We therefore recommend that this activity needs intergenerational support from video/digitally literate audiences such as younger people. The app was disliked by the majority of participants, which perhaps reflects the fact that it was not at an advanced stage of development and testing was only conducted with project staff. The app has not been rolled out further as a result. The school competition worked well and is a well-utilised method of engaging young people (Fogg-Rogers et al., 2017), however, policymakers should be aware that younger people do not have much agency to change their family or community behaviour, and so need support to further engage with older people who have decision making power (Laggan et al., 2022).

Policymakers should therefore employ a suite of appropriate activities for different demographics, expertise, education, and energy/accessibility levels, to ensure that public engagement reaches the full spectrum of citizens in society (Loroño-Leturiondo et al., 2019; McCallie et al., 2009). As recommended by Riley et al. (2021), more participatory engagement exercises can empower local people, increase ownership and agency, and result in higher levels of engagement with behaviour change. One size does not fit all, and so a variety of engagement activities are needed to ensure diverse citizen and community participation in climate change and air pollution policymaking.

4.2. *Learning, enjoyment, and behaviour change*

The overall aim of the ClairCity project was to raise awareness of air pollution, carbon emissions, and health, so many of the public engagement activities aimed to encourage learning in some form; encompassing changes in attitudes and values, enjoyment, knowledge and understanding, skills, and behaviour (Museums Libraries and Archives Council, 2014). The evaluation surveys varied due to the dwell time in the activities, but in general, enjoyment, understanding, and behaviour change intentions were assessed with up to 755 survey participants.

Overall, participants tended to enjoy the activities in which they took part, with a mean rating of 3.6 out of 5. There were statistically significant differences in how the activities were rated, and this negatively correlated to the age of respondents – in general the younger the participants, the more likely they were to say that they enjoyed the activity. This may be because more young people took part in activities purposely designed to be fun, such as the Skylines Game. However, across all activities, a statistically significant positive relationship indicated that the more participants enjoyed the activity, the more they also reported

higher understanding of air quality and carbon emissions. Similarly, the more participants reported increased understanding, the more they enjoyed the activity, indicating a co-linear relationship. Research into the relationship between enjoyment and understanding is complicated, with causal factors varying. Lu et al. (2023) similarly found a relationship which was moderated by age, with stronger patterns observed in younger citizens. Blunsdon et al. (2003) found that perceptions matter, with students who enjoyed the learning process reporting that they have learnt more, regardless of outcomes; and conversely Jack and Lin (2018) found that higher grade outcomes without concurrent enjoyment can lead to disengagement. Qualitative studies offer further insight into these mechanisms, with Lucardie (2014) reporting that adult learners perceived fun and enjoyment as motivational factors to attend classes, encourage concentration, and enable socially connected learning environments.

This relates to research into informal learning (McCallie et al., 2009; Wellcome Trust, 2012), indicating that people remember more information when the format is tailored to their situation – taking account of demographics, literacy levels and backgrounds – ensuring that participants can enjoy the activity and learn more. Similarly, learning is an enjoyable leisure-time pursuit, with research into science festivals indicating that audiences' prime motivation for attendance is learning new information (Fogg-Rogers et al., 2015; Jensen and Buckley, 2014). This also relates to intrinsic motivations for participating in an activity – whether it be the public engagement activity itself, the group context, or the learning process. Intrinsic motivation is developed when a participant feels autonomy, purpose, and mastery; i.e. people feel they have power over their situation, feel their participation matters, and gain satisfaction from developing skills (Pink, 2011). While we cannot determine causality in our study, it is clear that activities which are enjoyable and provide new relevant information to tailored audiences are important to deepen understanding of sustainability issues.

The ClairCity activities resulted in 74% of evaluators saying that they now intend to make a change to their lives to reduce emissions. Younger people and those with lower education were significantly more likely to indicate they planned to change their behaviour. Middle-aged participants were least likely to indicate they would change their behaviour in our study, which needs further investigation in future studies. Across all citizens, behaviour change intention was significantly positively correlated to understanding - the more participants reported that their understanding had improved, the more they reported intentions to change their behaviour. However, as previously discussed, behaviour is contextually and socially determined, indicating that not all these intentions will be continued into actual behaviour change (Chatterton and Wilson, 2014). It is interesting to note that in the open responses, while the positive behaviour changes described would improve air quality and reduce carbon emissions, the negative responses also indicated that situational or policy barriers were preventing participants from changing, rather than attitudes. Engagement activities are often criticised for attracting audiences already pre-disposed to science or pro-environmental behaviours (Jensen et al., 2015), and this effect cannot be eliminated from this study. Further work is needed to ensure diverse audiences are included in decision making processes, with engagement activities tailored to their contextual situation and understanding of the policy barriers towards relevant behavioural changes.

4.3. Towards enjoyable participatory citizen involvement in decision making

While climate change and public health are serious issues, public engagement to raise awareness and to improve participation in policymaking does not have to be. Enjoyment needs to be factored into the design of engagement activities, so that diverse audiences are motivated to participate and receive intrinsic rewards. This may be found in the playability design of serious games, (Loroño-Leturiondo et al., 2019), through ensuring community voices contribute to policy formation thereby enhancing self-efficacy (Yan and Davison, 2013), or through social engagement or vicarious experience with people in your social identity group (Bandura, 2004). Humans are inherently social creatures, and so activities which enable approval/reinforcement from peers (Fogg-Rogers et al., 2021), or which enable social participation through helping others or contributing to society (Levasseur et al., 2010) are more likely to ensure intrinsic reward.

The results from our study indicate policymakers should develop engagement activities which encourage creativity or playability relating to real-world emissions reduction topics or skills (Ye and Yang, 2023), or where participants feel that their voice will genuinely feed into decision-making (Liu et al., 2019; Riley et al., 2021). Enjoyable social learning decision-making activities could also play a role in enhancing life satisfaction for individuals through contributing to meaningful social participation (Levasseur et al., 2010), as well as enhancing community cohesion via enhanced understanding between social identity groups (Collins and Ison, 2009). More opportunities should be developed to enable social groups to learn from each other for climate action, whether between different demographics within cities, or between different cities across Europe and the wider world.

In our study, enjoyment was positively correlated with understanding, with the associated benefits of more impetus to act on climate change or air pollution or empower change for policy interventions. This adds weight to research by Brick et al. (2021), which indicates that core social goals drive climate action, including Belongingness, Understanding, Control, Self-Enhancement, and Trust, and this 'BUCkET' model is a more effective intervention target than attempts to create environmental beliefs or identities in individuals. Our study also indicated that understanding was significantly positively correlated with behaviour change intent. However, while intentions and motivation are pre-cursors to actual behaviour in the COM-B model (Michie et al., 2011), it is recognised that this is not always the case. Behaviour is affected by both internal and external factors, so participants may leave with best intentions, but psychological, social, financial, or political factors may mean that change is not realised (Chatterton and Wilson, 2014). Policymakers therefore need to plan to enhance the long-term legacy of public engagement and participatory activities, through creating a change-enabling environment.

External support would mean rapidly implementing positive policy changes such as those suggested by the citizens (Slingerland and Artola, 2020b), so that less-polluting behaviours become normative. Community focussed education projects have also been identified as an effective strategy for climate communications (Monroe et al., 2019), and so further consideration should also be given to enhancing the social capital of communities by empowering local role models or community assets (Fogg-Rogers et al., 2021; Mathie and Cunningham, 2003), or through supporting self-generated collective action within communities (Ntontis et al., 2020). Communicating co-benefits to behavioural changes, such as improved finances, health, or community cohesion is also important to attune to people's core values (Riley et al., 2021; Schwartz and Bilsky, 1987) and to ensure that policies do not generate unintended social or economic issues for citizens. A fair transition which benefits minorities or disenfranchised citizens is essential, as is ensuring policies also enhance biodiversity, so that carbon reductionism does not see the pursuit of emissions reduction at all costs.

Citizen-led policy suggestions can also accelerate emissions reduction compared to current business as usual policies. Quantitative modelling within the ClairCity project compiled the citizen policy preferences into a 'unified policy scenario' of citizen-led solutions for each city and region, with air quality compliance and low carbon emissions achieved much faster than current interventions (Slingerland and Artola, 2020a), adding further weight to calls for distributed decision making (Vlerick, 2020). Data scientists therefore have an important role to play in providing quantitative evidence and modelling to support citizen involvement in decision making, and we advocate for greater trans-disciplinary collaborations between community groups and

researchers.

To fully realise the goal of citizen-led emission reduction, researchers and policymakers need to ensure engagement is reflective of regional demographics and policies are co-developed with diverse communities. Engagement activities need to be tailored for each demographic group, accounting for age, gender and cultural identity, with personally relevant and meaningful information shown to have more impact (Hayhoe, 2021; Monroe et al., 2019). A breadth of experiences and expertise within both the research team (multidisciplinary and demographic) and between policymakers and communities can ensure the engagement efforts are co-created appropriately for the intended groups (Riley et al., 2020). Collaborative, creative, and enjoyable approaches to social learning mean citizens can learn from each other and negotiate shared solutions reflective of different social identities and values. Ultimately, the more enjoyable the engagement activities, the more people gain understanding about the issues, and the more likely people are to make a change to their individual and collective behaviours to reduce air pollution and carbon emissions and so improve public and environmental health.

CRediT authorship contribution statement

Sardo Ana Margarida: Methodology, Writing – review & editing. **Csobod Eva:** Conceptualization, Supervision, Writing – review & editing. **Boushel Corra:** Data curation, Formal analysis, Writing – review & editing. **Laggan Sophie:** Formal analysis, Writing – review & editing. **Hayes Enda:** Conceptualization, Funding acquisition, Project administration, Supervision, Writing – review & editing. **Fogg-Rogers Laura:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Laura Fogg-Rogers reports financial support was provided by EU Horizon 2020 No. 689289. Laura Fogg-Rogers reports a relationship with University of the West of England that includes: employment.

Data availability

Data will be made available on request.

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