**Integrated Multimedia City Data: Exploring Learning Engagement and Greenspace in Glasgow**

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*The present paper showcases a holistic, data-led, analytical approach to complex research questions about the associations between learning engagement and green spaces, and uses this exemplar to reflect on, and make recommendations relevant to, future implementations of CIM approaches to aspects of urban inclusion. This research offers a holistic picture of educational engagement, digital use, sustainability, cultural and civic participation, and transportation, employing data from diverse strands of the Integrated Multimedia City Data (iMCD) project in the Glasgow city region in the UK. This includes a household survey, individuals' travel diaries and GPS trails around the city, linked to other urban administrative datasets on area deprivation and greenspace. Triangulated findings from iMCD data indicate that greenspace is generally positively related to adult learning engagement (in particular, less formal learning), highlighting the value to urban planners of considering varied types of data capture for lifelong learning, with linkage to more objective measures of active mobility (e.g., walking) around the city. iMCD, in line with CIM approaches, offers an interdisciplinary bridge to address healthy ageing and educational inclusion. Insights generated in a CIM-based context can help education policymakers, city planners, and other educational stakeholders reconsider resource and infrastructure allocation, for instance, in promoting lifelong learning engagement for adults in urban settings.*

Despite the burgeoning interest in Smart Cities and City Information Modelling (CIM), little attention has been paid to how city design could affect the educational and learning engagement of adults. Existing research suggests that learning-engaged adults tend to be more socially engaged and physically mobile around cities, engaging in more active travel, as well as digital participation (Lido *et al,* 2016), but these patterns have rarely been tied to the components of the physical environment, and in particular proximity to greenspace. This paper begins to address this imbalance through analyses of data from the integrated Multimedia City Data (iMCD) project, a multi-stranded collection of urban datasets involving detailed person-level and sensed information about the city of Glasgow and its surrounding Local Authorities. Our aims are two-fold. The first is to demonstrate the use of a multi-stranded data approach to investigate learning embedded in urban spaces, in a CIM context, identifying its strengths, weaknesses and future potential. The second aim is to explore the relationship between adult learning and access to greenspace. We provide insights that city stakeholders may gain from multi-method analyses of openly available, linked datasets that are aligned with CIM approaches. These, although not necessarily collected for that purpose, illustrate the potential value and pitfalls of CIM-related approaches to urban and educational planning.

## 1. Background

UNESCO's Learning Cities agenda places learning at the heart of the economically, culturally and environmentally successful city (UNESCO-UIL, 2013). The concept of learning cities involves urban processes that facilitate lifelong learning opportunities at all ages and all educational levels through formal and less formal delivery mechanisms, using multiple, flexible learning pathways, entry and re-entry points (UNESCO-UIL, 2017, p. 12). The Sustainable Development Goals, particularly SDG 4, have highlighted lifelong education for all as a human right. Education in this context covers what takes place not only in formal educational settings, from nursery to higher education, but also in less formal places, where 'lifewide' learning may flourish. This lifewide dimension is particularly pertinent since it emphasises that learning is not confined to formal settings, but takes place in multiple circumstances such as the "home, community, playground, workplace, sports yard, mass media, through play, conversation, debate, reading, writing, teaching, problem solving, social participation, social service, travel, use of ICTs, and so on" (UIL, 2011, p. 45), all of which are places or situations considered amenable to design by CIM.

Many studies have revealed the worldwide inequalities of access, retention and attainment in formal learning programmes (e.g., Osborne *et al.*, 2015), which have persisted or even worsened, despite decades of interventions (Osborne, 2003). Studies of informal learning, which is unstructured, without clear objectives and located outside formal institutions, are also of interest to educators (Adult Education Survey, 2015), but systematic and multi-modal approaches that assess this form of participation in cities, making links with other key

variables, are scarce. This is especially the case for place-based factors, such as access to greenspace, a particular focus of this paper. We consider it important to capture all forms of learning engagement of adult learners, including the informal, since they are strong indicators of health and well-being, and of vibrant places. This is especially the case for those people who are most excluded in society, for which reason our analyses centre on two groups who are marginalised in educational participation: the elderly (60+ years old) and those from deprived areas (Lido *et al.*, 2016; Osborne *et al.*, 2015; Stuart *et al.*, 2011).

Despite the initiatives aimed at developing 'age-friendly cities' around the world promoted by the World Health Organization (WHO) (2007) (see also Buffel, Phillipson & Scharf, 2012), older adults in particular are frequently marginalised socially and educationally because they may be physically more isolated and less mobile in urban spaces, and due to the consequent risks to their mental and physical health (e.g., Locher *et al.*, 2005; Coyle & Dugan, 2012; Shankar *et al.*, 2011), which thereby makes the marginalisation difficult to assess. More holistic, evidence-based research may help identify the drivers of older adults' learning engagement. Emerging technologies may be key to evaluating lifewide learning embedded in the lived reality of their urban environments. A more complete knowledge of the two aspects may suggest means by which learning engagement may be boosted, particularly among older adults.

City Information Modelling is a new adaptation of the Building Information Modelling (BIM) technologies that seek to address the changes facing cities by integrating BIM- at different spatial scales- into wider city planning and development (BIM Today, 2018; Maxwell, 2018). With CIM, city planners and other relevant stakeholders can access all key information about various city aspects, modelling potential impacts of existing or new urban projects and policies. The many benefits of CIM include centralising citywide information for quick and easy access; facilitating collaboration and cooperation among stakeholders and providing support for collective decision-making; facilitating engagement between city managers, policymakers and the general public; and increasing city sustainability (Maxwell, 2018). Greenspaces and people are important elements of any city that should be accounted for in CIM. In this paper, we hope to better understand how city dwellers engage with urban greenspaces, and how this engagement is related to their learning engagement. It is our expectation that findings of this nature will be critical for informing city planners and policymakers about the future city designs that will encourage lifelong learning opportunities across all age groups and educational levels. This is especially pertinent given the increasing interest in the implementation of smart, future and 'Learning Cities' in many countries.

## 2. Adult Learning and Greenspace

We now review the literature on adult learning and greenspace, since this is germane to the application of CIM to diverse data strands exploring relationships between greenspace, physical mobilities and lifelong learning engagement. It is well established that the presence of residential and community greenspace in urban environments has wide-ranging beneficial

effects on physical and mental health and wellbeing, even in deprived neighbourhoods (see Braubach *et al.,* 2018), albeit with some debate about the optimal amount of 'green' (e.g., Wolch *et al.*, 2014; Bertram & Rehdanz, 2015). Physical regeneration and promotion of active travel appear to be key elements in urban planning to combat inequalities in well-being (Barton, 2009), and further to this the provision of optimal levels of greenspace may play a mediating role (Wolch *et al.,* 2014). Given this, we hypothesise that the positive presence of greenspace, much like active mobilities, might also relate to learning engagement and attainment. Holistic place-based approaches, such as the EcCoWell strategy promoted by the Pascal Observatory (Kearns, 2017), stress the intersection of green and sustainable cities for successful lifelong learning engagement, but little research effort has been directed towards investigating such associations. Part of our programme of work is therefore concerned with addressing this knowledge gap.

The benefits of greenspace may be realised through diverse processes Some of these are passive, a matter merely of living near greenspace (Houlden *et al*., 2018; Astell-Burt *et al*., 2013; Lachowycz & Jones, 2013). For instance, people living near greenspace are more likely to use it than those living further away, in a proximity effect (Kaczynski & Henderson, 2007; Ward Thompson & Silveirinha de Oliveira, 2016). Other pathways to greenspace benefits may involve more active use, through walking, cycling and other physical activity (e.g., Mason & Kearns, 2016; de Keijzer *et al.*, 2016). Therefore, people living near greenspace may be more likely to be active travellers in and around these spaces, such as walking through them for leisure or commuting purposes (Giles-Corti *et al.*, 2005; Sugiyama *et al.*, 2014). However, such greenspace usage patterns are not straightforward, for example, there will be age and gendered variations in such use (Richardson & Mitchell, 2010; Astell-Burt, 2013; 2014). In addition, there may be an interaction of active travel with vehicle use, for instance in areas of deprivation where walking may be an economic necessity (not owning a car), rather than undertaken for mental of physical health reasons (Ogilvie *et al*, 2008).

Our work has previously revealed that adults engaged in lifelong learning are more likely to report fewer long-term health issues and to be more physically mobile, for instance walking more, around their cities (Lido *et al.*, 2016). This is consistent with evidence associating lifelong learning engagement with better overall life outcomes, particularly with respect to physical and mental health (Marmot *et al.*, 2010; Chandola *et al.*, 2011; Rossor & Knapp, 2015; Schuller, 2017), employment and related financial security (Bhutoria, 2016), and social and community engagement, including civic and democratic participation (Feinstein *et al.*, 2008; Finkel, 2014).

The literature reviewed above supports associations between greenspace and health, as well as learning and health. An emerging field of research has begun to link proximity to greenspace with generally positive formal learning outcomes in children, such as academic achievement, performance on standardised tests (see Browning & Rigolon, 2019) and attention (Dadvand *et al.*, 2017; 2018). More specifically, Kweon *et al*. (2017) noted an association between the number of trees near schools and standardised test scores of school

pupils. There are exceptions, nevertheless. For example, Beere and Kingham (2017) reported a negative relationship between greenspace and primary school achievement in New Zealand.

The links between greenspace and learning in adults are even less well-established. The scant research in the area focuses on non-formal and informal adult learning occurring within greenspaces (e.g., community gardens as spaces for learning; Cumbers *et al.,* 2017; Hou, Johnson & Lawson, 2009), or outdoor learning for adults (e.g., Bendt *et al.,* 2013; Krasny & Tidball, 2009). Digby (2013) indicates that less formal learning engagement may be the best path to environmental learning and promoting environmental behaviours, and there is an ever-increasing interest in adult environmental education 'outside' formal classrooms and curriculum (notably the work of Clover, 2002; 2003, and, more recently, Hall *et al.*, 2013; Clover, 2016). Cherrie *et al.* (2018), using retrospective life course analysis, even suggest that proximity to greenspace in childhood may have later cognitive benefits in older adulthood in Scotland. The name of the city of Glasgow stems from early Brittonic roughly translated as 'Green Hollow, leading to the nickname 'Our Dear Green Place' (James, 2007). Despite its industrial history, Glasgow regularly ranks in the top 3 cities in the UK for greenspace, under its fellow Scottish city of Edinburgh (e.g. Guardian, 2017). Therefore, the present research seeks to explore diverse data strands to better understand the relationships between proximity to greenspace, physical mobility and lifelong learning for adults in the Glasgow City Region area of Scotland, UK.

## 3. The integrated Multimedia City Data (iMCD) project

### *3.1 Overview*

The integrated Multimedia City Data (iMCD) project was set up to examine how values, attitudes, beliefs, and education influence the behaviours and activity of urban citizens of the city of the other eight local authority areas comprising the Glasgow City Region (Glasgow, East Dunbartonshire, West Dunbartonshire, Renfrewshire, East Renfrewshire, Inverclyde, North Lanarkshire and South Lanarkshire). Its conception and execution are described more fully in Thakuriah *et al.* (2020). Its innovative strength resides in its five linked data strands and the potential to combine these with external administrative datasets to generate novel, analytical synergies (see Lido *et al.,* 2019, for iMCD as Learning City metrics). The linked data strands detailed below are: household survey; travel diary; and GPS trails, subsequently linked with data on deprivation and greenspace.

The iMCD methodology was first proposed by Thakuriah and Geers (2013), based on infrastructure-based data (e.g., mobile and wearable sensor data) alongside background data from administrative data sources, providing a sociodemographic context, as well as indicators of built environment and place-based attributes. Prior examples of this approach are demonstrated in the Chicago area Spatial Decision Support System (Cottrill & Thakuriah, 2010; 2011). Thus, many of the features of iMCD fit comfortably within CIM's conceptual framework, such as the links between physical components of holistic city planning and less

tangible, but equally important, aspects of health and wellbeing, and the ways people may flourish through living in an urban environment. This enables us to provide an applied example of how our diverse data streams can "create the integrated and comprehensive information model of the city" referred to in the introduction to this special issue (Gil, 2020).

### *3.2 Participants*

The present project was approved by the University of Glasgow's research ethics committee and was conducted in line with British Psychological Society ethics for research on human participants. A representative sample was taken of households in the Glasgow City Region, accomplished using the services of the Ipsos Mori survey company, who employed a stratified random sampling design, using the Royal Mail Postcode Address File (to ensure a representative sample of the population with respect to age, gender and ethnicity). Selected households were approached via letter and phone for a face-to-face interview of all eligible adults in the household. The sample was also stratified by deprivation for a roughly even number of respondents in each decile of the 2012 Scottish Index of Multiple Deprivation (SIMD). The primary strand of the iMCD project, the household survey, comprised a sample of 2095 participants from 1505 households, of whom 54.3% were female. Ages ranged from 16-102 years, the average being slightly older (49.42 years; SD= 19 years) than the Scottish national average age for adults in the 2011 Census (National Records of Scotland, 2015), but a figure largely in line with other surveys, such as the Scottish Household Survey (2015). For the purposes of the analyses presented here, we consider 'adults' to be participants aged 16 years or more, and 'older adults' to be those aged 60 years or more.

### *3.3 Measures*

(a) *Household Survey*. The household survey assessed individuals' behaviours, attitudes and competencies in the domains of education, transport, sustainability, technology, and cultural and civic engagement. It was developed following an exhaustive review of (largely UK) national survey questions in the domains of interest, and assessment of content validity by a team of eight subject-matter experts from inter-disciplinary backgrounds. The draft survey content was compared against the 42 UNESCO-UIL (2013) features of Learning Cities to target key indicators of the successful Learning City. Demographic information was also collected about individuals, including age, ethnicity, nationality, migrant status, relationship status and religion, and about households, such as the number of children and income.

Three types of learning engagement are considered here: formal, non-formal and informal learning[1]. These were operationalised from the definitions of UNESCO-UIL (2013) and Werquin (2010) and aligned for consistency with those of the Adult Education Survey (2015) and Organisation for Economic Co-operation and Development (OECD, 2016). Lido *et al.* (2016) present a more detailed justification for examining this range of learning modes.

Participants were asked in some detail about the nature of their involvement with each type of learning engagement once their participation (or not) was established by their responses ('no' or 'yes') to three questions: (1) [formal] *During the last 12 months, have you taken part in any course or apprenticeship intended to lead to a recognised qualification, regardless of whether you completed the course or obtained the qualification?*; (2) [non-formal] *During the last 12 months, have you taken part in any course or apprenticeship that was not intended to lead to a recognised qualification (a course is a series of structured learning activities)?;* (3) [informal] *Apart from the structured courses or training we've already talked about, have you done anything independently to learn something in the last 12 months, such as learning a language, a hobby, reading in the library or online, or teaching yourself new skills at work?*

Participants' survey data were subsequently linked to neighbourhood-level administrative data (i.e., measures of greenspace access and area deprivation) via their home location (information otherwise stored separately from participants' survey responses and other data), as detailed below.

*(b) Urban greenspace access* was determined by superimposing the Open Street Map route network on the Ordnance Survey's Greenspace map for identifying accessible recreational and leisure greenspace. For each respondent, it was determined whether the nearest access point to several types of urban greenspace lay within a 10-minute walk of their home postcode centroid. These types of greenspace were: (1) public park or garden; (2) publicly accessible sporting greenspace (playing fields, golf courses, tennis courts, bowling greens, etc.); (3) play spaces. Other types of urban greenspace (allotments, community growing spaces, religious grounds and cemeteries) are not considered in this paper. Likewise, natural greenspaces (e.g., woodland and meadows), farmland and water bodies (e.g. rivers, canals, lochs and reservoirs: 'bluespace') are not included in our analyses.

*(c)Area deprivation* is a neighbourhood-level factor known to affect educational attainment. In Scotland this is quantified by the Scottish Index of Multiple Deprivation (SIMD), which provides overall ranks of deprivation for the country's 6976 data zones (the smallest area geography for which administrative data are available). For our analyses, we linked participants through their home postcode to the 2016 SIMD quintile or decile of overall deprivation.

*(d) Travel diary.* Participants' travel diaries were collected immediately after the iMCD survey (valid n= 1287). In order to ensure the diaries were more representative of travel patterns of the population in the Glasgow area, interview dates were allocated as evenly as possible across the week, given that only a single day of travel was captured for each participant. Participants were asked a series of questions recording all trips made for the day preceding their survey interview. Details of travel origin, destination, time, mode and purpose were collected for each trip. The self-reported frequency of walking trips was subsequently extracted, based on the information about the mode of travel. These quantitative data about active travel were then linked to the survey data.

*(e) GPS trails.* Upon completion of the household survey, participants were asked if they were willing to take part in further iMCD research. 333 people agreed to the recording of GPS trails, with data from 305 participants (116 of whom lived in the City of Glasgow) valid for analysis. A GPS device worn by each participant saved the coordinates of their location at 5-s intervals over 2-11 days, thereby enabling their movements to be tracked as journey trails using the QGIS. These GPS data were cleaned (e.g. erroneous locations) and classified by travel modes (using OpenStreetMap and Barefoot, for further details see Sila-Nowicka & Thakuriah, 2019, or submit research query to ubdc.ac.uk).

Walking was distinguished from the other modes of travel, and total daily walking times were calculated for each participant. By examining the intersection of GPS trail trajectories with greenspace (as per Ordnance Survey's Greenspace dataset), separate measures of time spent walking in, or within 20 m of, greenspace were also calculated. To avoid zero-duration values, which arise when coincidence with greenspace lasted less than 5 s (producing a "start" but no "finish" time stamp), 5 s were added to each duration to take into account the time approaching and distancing from greenspace. Linking the GPS and greenspace data to the main survey, via deidentified respondent IDs, allowed GPS patterns to be examined in relation to levels of adult learning-engagement.

### *3.4 Hypotheses*

Our primary purpose is to evaluate, through example, the opportunities and limitations of initiatives such as the iMCD project for addressing research hypotheses, rather than to present exhaustive results from each of the analytical avenues explored. Our overarching research interest is the relationship between adult learning engagement and access to, and use of, greenspace, irrespective of any influence of area deprivation. We seek to answer our research question by triangulating the findings from complementary analyses that address specific research hypotheses using iMCD's different data components, and combinations thereof.

We propose three research hypotheses (H1-H3), listed in Table 1, offering these as an exercise in the application of linked iMCD and administrative data strands to address issues of urban inequality. We then present selected results from the analyses to examine each hypothesis. In light of these results, we assess how the integration of urban data streams could create synergies of value in urban planning, and consider the policy and planning implications of such approaches for the improved development of targeted interventions, in this instance, to promote place-based learning. We conclude by outlining how greenspace and active travel, alongside emerging technologies, can be incorporated into CIM to facilitate the development of a city like Glasgow as a sustainable, healthy, learning city, in line with UNESCO's framework of indicators (UNESCO-UIL, 2013).

INSERT TABLE 1

## 4. Analyses

### *4.1 H1: Proximity to greenspace is associated with adult learning engagement*

The maximum sample of 2090 valid adult respondents (between 5 and 23 cases were excluded because their data were incomplete) comprised 34.1% aged up to 39 years, 33.7% between 40 and 59 years, and 32.3% aged 60 years or more. Around twice as many respondents (34.1%) lived in one of the top 20% most deprived neighbourhoods in Scotland than in the 80% less-deprived neighbourhoods, reflecting the disproportionately high levels of deprivation in Glasgow City Region compared with rest of Scotland.

***Almost all respondents (98.9%) were within 10 minutes' walk of one or more types of greenspace,*** the values for the separate types varied considerably: public parks and gardens, 57.6% of respondents; play spaces, 90.8%; playing fields, golf courses and other sporting facilities, 78.5%; other urban green spaces (e.g., allotments, religious grounds, cemeteries etc.), 82.0%. ***The great majority of people in the sample were not learning-engaged;*** overall, 10.5%, 7.4% and 10.9% of those interviewed had undertaken some formal, non-formal or informal learning in the previous year, respectively. 76.9% of the sample were not learning-engaged in any way. Of the 23.1% who were learners, most (18.5%) were engaged with just one form, 4.0% in two forms, and 0.6% undertook some of all three forms of learning engagement.

Percentages of learning-engaged respondents by sociodemographic and other groups are summarised in Table 2. It is clear that ***learning engagement falls dramatically with age, to near negligible levels amongst the oldest respondents***; none of the participants over the age of 79 years (6.9% of participants) reported being engaged in any form of learning. Unsurprisingly, only a very small percentage of older adults were involved in formal education, for whom informal learning is the most common learning route. ***Informal/self-directed learning is relatively the most frequent form of learning engagement for adults and older adults***, although absolute levels are much lower than in the other two age groups. Participants in the City of Glasgow were significantly less likely (by about 60%) to have done formal learning than those in the adjacent Local Authorities, but conversely were about 1.9 times more likely to be informally learning-engaged. People living in the most deprived neighbourhoods across the entire area were around 0.7 times less likely to be learning-engaged in some way, most of this pattern being ascribable to the rate of uptake of informal learning. Notably, there was no substantive difference in the proportions of learning-engaged men and women.

Considering the associations with greenspace independently of other factors, there appears to be a ***positive link between informal/self-directed learning and close access to parks and gardens (1.3 times as likely), play spaces (2.0), and playing fields and sports grounds (1.7)***. However, there were no significant links for formal and non-formal learning.

Logistic regressions further explored associations of the proximity of access to greenspace, age group and neighbourhood deprivation with participation in the previous 12 months in types of learning (note: gender was dropped from the model as it was never a significant factor). For ease of comparability, the models included all three independent variables, irrespective of their statistical significance. No interaction terms were significant. Odds ratios and other regression statistics are presented in Table 3.

Our results give general support to ***hypothesis (H1), that proximity to accessible greenspace is associated with significantly greater learning engagement.*** Regressions reveal that close access to parks and gardens, play spaces and sporting greenspace was associated with significantly greater likelihood or participating in one or more types of learning (OR = 1.27, 2.16, and 1.58, respectively). This pattern appears to be primarily attributed to significantly higher odds of involvement in ***informal learning engagement through proximity to each of the three types of greenspace*** (OR = 1.45, 2.25, and 1.87, respectively). Other parameter estimates that were close to significance ($0.05 \leq p < 0.10$), which might suggest that certain aspects of greenspace and learning, where cell sizes dwindle, may warrant further investigation; for example, to explore whether proximity to parks and gardens and play spaces might be linked to greater formal learning engagement, or if living near play spaces and sports grounds might make people more likely to participate in non-formal learning.

Overall, the models in Table 3 explain 5.9-11.2% of the variation in the types of learning engagement. These values are low but should be considered in light of the multitude of other influences on learning engagement not measured by iMCD, such as prior educational experience and parental educational background.

The models also demonstrate ***the starkly lower levels of learning engagement amongst the older (60+ years) participants.*** This is most marked, unsurprisingly, with respect to formal education (OR= 0.11, i.e., around 9 times less likely), since none of this group will be in school, and few will be in Further or Higher Education. This is also a notably lower level of participation in non-formal learning (OR= 0.22, i.e., about one-fifth as likely), probably because much of this may occur in a work-related context. However, urban design through CIM might be particularly appropriate to stimulate informal learning among the older group, who, our models suggest, are two-and-a-half times less likely (OR= 0.42) to be learning-engaged than their younger counterparts.

Deprivation also plays a role in these outcomes, as those who lived in the 20% most-deprived neighbourhoods of the eight Local Authorities were little more than half as likely to be recently engaged in some type of learning (compared with people in the 80% less deprived neighbourhoods; OR= 0.56). This means that ***those in the least deprived areas were twice as likely to engage in formal or non-formal learning than those living in more deprived neighbourhoods***, when accounting for proximity to parks and gardens and to children's play spaces.

INSERT TABLE 2

Lido *et al*. (2016) previously demonstrated that learning engagement decreases sharply with age, and that area deprivation is a key factor associated with lifewide learning engagement. We extend these findings, by gathering support our hypothesis that there is a positive association between proximity to greenspaces and learning engagement, with urban environmental drivers being a particularly strong influence on informal/self-directed learning. However, we found no evidence that these patterns of greenspace-related engagement were any different among the older adults than they were among the younger adults; the former group's low proportions of participation may most simply be explained in terms of age alone.

**In summary, our analyses support previous findings that learning engagement declines with age and in areas of greater deprivation. Additionally, we find evidence to support H1, whereby greenspace is associated with greater learning engagement overall, particularly informal/self-directed learning in relation to local access to greenspace.**

INSERT TABLE 3

Of course, these data do not address whether or how participants make use of their local greenspaces. The first of these two aspects is dealt with by studying participants' GPS trails (H2) and by linking the survey to the travel diaries (H3). In the context of the broader, multi-component nature of the iMCD project, we will see how the results from one component can complement and thereby shed light on those of another.

### *4.2 H2: Learning engagement is associated with greater active mobility, particularly around greenspace in the city*

Further summary statistics were calculated, and regressions were run to test this hypothesis, specifically exploring mobilities, using travel diary and GPS indicators of walking. Despite their being considerable variation between individuals, on average there were only small differences in the times spent walking anywhere and walking specifically in greenspace between learning-engaged and non-learning-engaged adults in the younger and older age groups (Table 4). This suggests that consistently, for the three separate learning-engagement components, and ***for learning engagement of any type, learning-engaged adults spend more time walking anywhere, and specifically in greenspace, than do non-learning-engaged adults.*** Older adults spend less time walking, overall or in greenspace, than do younger adults.

Walking durations are extremely skewed, with a large proportion of people walking for a shorter period, and a small proportion walking for longer periods. To analyse walking time in greater detail, therefore, these outcomes were log-transformed to better approximate more normally distributed variables, in order develop ordinary least squares (OLS) regression models that included age group and learning-engagement status. Both factors were fitted, regardless of their statistical significance. Results for the two sets of models (walking anywhere; walking in greenspace) are presented in Table 5. Other model terms were also explored (e.g., the month in which the GPS walking data were collected) but the results are not presented here as these terms never yielded significant parameter estimates, and thus the model was constrained to include fewer predictors those for H1 (excluding factors such as gender, area deprivation, and the age group * learning engagement status interaction).

It is clear from these analyses that there are small, but ***significant differences in the log-transformed overall walking times between the learning-engaged and non-learning-engaged participants' mobilities.*** As predicted, participants who were learning-engaged in any way walked for slightly but significantly longer periods than did non-engaged people. Looking more closely, with respect to the type of learning with which participants engaged, it is apparent that this pattern tended to be associated with formal and non-formal learning, but not with informal learning. We also note that, again, as would be predicted, older participants walk for significantly less time than do younger ones, whether they are learning-engaged or not.

INSERT TABLE 4

However, considering the time spent walking specifically in greenspace, despite the values being consistently higher for the learning-engaged and the younger group compared with the non-engaged and the older group, respectively, the magnitude of the differences was too small to be significant for the relatively small number of participants we were able to consider.

In truth, ***participants spent very little time walking, on average, and especially so in greenspace***. This makes it difficult to distinguish differences that arise between the two learning-engagement status groups, as is reflected in the very small proportion of the variance explained by the models (no more than 4.3% and 1.4% in the overall and greenspace-only models).

**In summary, we find partial support for H2, as there is evidence that learning-engaged adults spend more time walking in any type of urban environment. However, there was no clear evidence that learning engagement is associated with spending more time walking in greenspace.**

INSERT TABLE 5

The H2 analyses do not address the location and diversity of greenspaces within which respondents walked. For this purpose, we turn to H3, which we tackle with further analyses of walking data in the travel diary, supplemented with GPS trail data.

### *4.3 H3: Learning engagement is associated with walking, especially in greenspace, as evidenced by travel patterns*

Given the findings above, it is useful to draw upon the householder survey and GPS statistics above and complement them with the travel diary and a more qualitative exploration of where and people are moving with detailed GPS trail images, to examine the relationship between learning engagement (whether a person had engaged in one or more of the three types of learning: formal, non-formal or informal) and the number of days in a week when they walked (in the first instance), as well as where they walk (in the second instance). Thus, we ran multinomial logistic regression models, with age now fitted as a continuous variable (given its explanatory strength), using the full sample of all adults, and then with the sub-sample of older (60+ years) people. Participants were asked in the survey *On how many out of the last seven days, did you make a trip of more than a quarter of a mile by foot?* For our analysis, the responses were recategorized as: 0 days, 1-4 days or 5-7 days. The survey also asked about attitudes towards active travel (i.e., how positively or negatively they felt about walking, cycling, etc.). Regression model results are shown in Table 6 below.

Results reveal that the attitude towards walking is significantly associated with actual walking patterns for adults, and older adults in particular, whereby people who like walking tend to do so on more days than those who do not, even when other sociodemographic factors and neighbourhood characteristics are taken into account. The results further show, as regards H3, ***adults engaged in learning are more likely to walk on most days (5+ days) than those who do not.*** This provides initial evidence consistent with their being a positive influence of learning engagement on active mobility around the city. However, it is not possible to detect whether this relationship holds among older adults, given the small number of participants for whom valid data were available. When removing *Age* variable from the model, *Learning* is not significant, but reveals a pattern in the predicted direction ($p < 0.10$) when comparing those who do not walk (0 days per week) with those who do walk (1-4 days per week), suggesting future research should explore learning and walking, particularly with greater numbers of adults 60+. Finally, our results ***fail to indicate any significant association between accessibility to parks and gardens and the frequency of walking days.***

The travel diary includes information about all trips (e.g., travel modes, purposes, duration, distance, etc.) participants made on the day before they were interviewed. People who made no trips did not contribute a travel diary. We calculated the frequency (total number) of

walking trips per person from their travel diary and examined this outcome by negative binomial regression, similar to a multiple regression whereby the dependent variable is observed as a count. This type of modelling is widely used to analyse count data (e.g., total number of trips) that are over-dispersed (i.e., whose variance is greater than their mean). We also calculated average daily walking hours from the GPS data, and examined the relationship between walking hours and learning engagement by linear regression, having square root-transformed the walking hours to reduce their skewness. As Hong *et al*. (2019) revealed, short walking trips in the iMCD survey (both self-reported in the main survey and travel diary) may be under-reported, so using a more objective measure of walking hours from GPS data alleviates such bias when testing H3 (sample sizes for final analyses with travel diary and GPS data are 1,287 and 275, respectively). Results from the travel diary regarding learning and walking associations not reveal a significant positive association between walking behaviour and learning engagement, but do suggest a pattern (travel diary data: p=0.069; GPS data: p=0.112) in line with the conclusions of our previous analyses for H1 and H2, or those of Lido *et al*. (2016)[2].

INSERT TABLE 6

We then quantitatively compared average (log-transformed mean) times spent walking, overall and specifically in greenspace, for participants who walked in the City of Glasgow (for whom GPS trails were available). In order to account for unequal cell sizes of those learning engaged (minority) and those non learning engaged (majority), match pairs were selected by gender, 5-year age group, Local Authority of residence (Glasgow *vs.* other LA), home neighbourhood deprivation (most deprived SIMD quintile *vs.* less deprived quintiles), and the time of year the data were collected (May-June; July-September; October-November). The resulting 53 matched pairs were compared using paired-sample t-tests. Although the mean times of overall walking and of walking in greenspace were slightly longer (by less than 1 minute) amongst the learning-engaged group, the differences were not statistically significant apparently due to the high degree of variation between individuals' walking durations. This highlights the difficulty, even when starting with comprehensive data, from a relatively large sample of participants, of extracting conclusive quantified patterns about strictly defined sub-groups of citizens, and therefore we move to qualitative interpretations of GPS patterns for the older adult sub-sample to explore H3 further below.

**In summary, we find initial support for H3, that adults engaged in learning walk more than those who are not engaged in such learning, when using GPS metrics combined with survey and travel diary metrics.**

Additionally, the difference in GPS total time walking in greenspace between learning-engaged and non-engaged adults in our sample is not statistically significant for the sample overall, with a Welch F-statistic on the log-transformed variable for time spent walking in greenspace of 2.97 (d.f. = 1, 182.97; p= 0.087) (excluding cases with 0 min walking). However, for the older adult sub-sample, it is statistically problematic to explore even with non-parametric equivalents, so we turn to a qualitative interpretation of GPS maps for 60+ year old adults to visualise their greenspace walking more naturalistically.

Figures 1 and 2 allow us to view actual patterns of movement around the city, and within it urban greenspace. It can be seen that the mobility patterns differ between learning-engaged older adults (orange lines) and non-learning-engaged adults (blue lines) for both all travel mobilities, as well as walking more specifically. For the purposes of mapping and presenting patterns of walking, we considered the 52 participants aged 60+ years (7 and 3 learning-engaged women and men; and 23 and 19 non-learning-engaged women and men, respectively) whose walking trails were wholly or partially situated in the City of Glasgow. There were no gender differences in these patterns, but they qualitatively suggest that, especially when walking, non-learning-engaged adults are more mobile in and around greenspace than their learning engaged counterparts, who seem to spend more time walking in central urban locales. This contrasts with the expectation under our hypothesis, and with previous findings (Lido *et al*., 2016) suggesting that learning-engaged older adults are more physically mobile around their urban environments. However, the findings are consistent with those from the iMCD survey, as ***learning-engaged older adults may be more mobile overall in urban spaces, but not necessarily in greenspaces.*** These maps indicate a more complex relationship between greenspace and learning engagement for older adults than that of a straightforward link between more active travel among learning-engaged older adults in all urban settings.

INSERT FIGURES 1 & 2

These maps qualitatively illustrate the trajectories of participants as they move through the city, including through urban greenspaces. As we will see below, these observations can be

triangulated with the quantitative-based story of time spent walking in the city and within city greenspaces emerging from our examination of hypotheses H1 and H2.

## 5. Discussion

### 5.1 *Triangulated findings*

We have explored greenspace as statistical survey data and mapped matrices, adding 'layers' of GPS movement trails, whilst considering complex personal attributes, with linked IDs, in terms of their demographics and learning engagement, all of which fits with the CIM advocacy of moving from 2D representations (trails and statistics) to 3D conceptions of how people are learning and engaging within as they live and move within these green city-spaces. Overall, we find support for H1, that proximity ***to greenspace is associated with adult learning engagement*** for our survey sample of adults (16+ years), ***particularly for informal learning***, but the effect did not hold specifically for older adults (60+ years). We further find support for H2 and H3, that ***learning engagement is associated with active mobility in the form of walking*** from GPS measures, and attitudes to walking assessed in the household survey. This is also hinted at by the patterns noted from the study of travel diary records of walking support learning associations in the predicted positive direction, but failing to reveal significance. Therefore, the findings support that adults engaging with learning were more likely to engage in active walking around their city, although, once more, this effect was not demonstrated for the older adult (60+ years) sub-sample. Although we found evidence to associate greenspace with learning engagement, and learning engagement with active travel, ***we were unable to demonstrate quantitative links from learning engagement to mobilities specifically in and around greenspace*** as mapped in the city via GPS**.** Qualitatively, however, it appears that learning-engaged older adults may be more mobile around central urban spaces, whereas non-learning-engaged adults appear to be more mobile around greenspaces in the city than younger adults.

The triangulated conclusions reveal a rich and complex view of learning engagement for adults in the city, in terms of their proximity to greenspace and active mobility (walking). Taken together, our analyses reveal a generally positive relationship regarding engagement in adult learning and proximity to greenspace, as well as engagement in learning with active mobilities around the urban environment (particularly for informal, self-directed types of learning engagement). Although we could not close the loop by identifying a connection between learning engagement and mobilities within greenspace specifically, there is a tentative indication that it would be worth looking further into the possibility that learning-engaged older adults use urban spaces in different ways from non-learning-engaged older adults. Overall, these example analyses highlight learning and greenspace as areas in which CIM approaches could be applied in future to better inform lifelong learning engagement in Learning Cities. For instance, if in Glasgow greenspace proximity and use emerges as linked

with self-directed learning and active mobilities, it may be that active mobility within greenspace is itself learning, as well as a facilitator of learning.

INSERT FIGURE 3

* Original Figure with underlying photo '*CityTree phytoremediation, Glasgow City Centre, Scotland. Installed by Glasgow City Council'*.
Credit to: Attribution-ShareAlike 4.0 International (CC BY-SA 4.0). Accessed via: https://creativecommons.org/licenses/by-sa/4.0/deed.en

Figure 6 demonstrates the story of these preliminary findings and embeds them within the Learning Cities Framework, and within the City of Glasgow specifically. The photo image (credit above), illustrates a 'City Tree' or 'Urban Plant Wall' (Splittgerber & Saenger, 2015) with bench seating below, prompting us to think about how greenspace proximity, informal learning and active mobilities can be brought together for inclusive urban interventions. At this stage, these GPS analyses are largely descriptive and exploratory, and statistical modelling of walking mobilities among these participants at times are unable to establish the statistical significance of some marginal patterns emerging in the data. However, future analyses of the more detailed walking metrics we have (e.g., velocity, time spent standing), and the identification of other forms of active travel, especially cycling, are certainly warranted.

We now discuss the potential implications and limitations of iMCD for stakeholders, including academic researchers, policymakers and citizen users, within the contexts of the Learning Cities and CIM paradigms.

### *5.2 Implications & Limitations of Citizen-user engagement*

Given the interesting early indications that greenspace proximity and mobility within it are of value when considering the promotion of adult learning in the city, the diverse data collection described above illustrates the need for CIM-type approaches to learning inclusion, to better integrate and mobilise the sources of existing data on learning and urban environments. Such CIM approaches may be beneficial in aiming to achieve SDG4, 'lifelong learning opportunities for all'. However, Gil *et al.* (2011) highlight the very real challenges facing CIM, namely data integration, seamless interfaces and privacy versus accessibility tensions. Our 'snapshot' analyses raise broader questions, such as how best to triangulate findings from diverse and at times unwieldy data-strands and real-world indicators (such as indicators of greenspace, active travel and learning metrics), and make them more useful to a wide range of urban stakeholders. We have demonstrated the potential for , as well as the limitations on, in drawing meaningful conclusions from linked data collected, at different output scales and in a variety of formats. Their analysis required a variety of quantitative approaches, interdisciplinary frameworks of interpretation, as well as qualitative narratives (as seen with the GPS maps), making it challenging to integrate conclusions into a coherent evaluation for stakeholders. Likewise, IDs for survey and GPS can be difficult to match, and- as

demonstrated- travel diaries may have low validity when used in isolation. Therefore, even when data like those comprising iMCD are openly available for access and manipulation by, for example, lifelong learning policy-makers, it remains less clear how they can be better integrated and made more usable for onward use by stakeholders external to discipline-specific research teams.

We have begun to address the research questions above by using various combinations of data strands and analytical methods, contrasting them with the ambitions of CIM to meet these aforementioned challenges (data linkage, integrative analysis and policy-maker access), and in our analysis we have learnt about the potential benefits of strongly integrated and embedded CIM-based ethos, from the point of data collection to dissemination. The consequences of this insight become apparent when integrating diverse data strands on a broad range of activities, such as learner engagement, and managing the formats and visualisations of such engagements around the city for ease of use by varied urban stakeholders. We acknowledge the potential of integrated open data products, such as iMCD, to encourage urban stakeholders to address challenges in their city, from transportation and inclusive mobility to sustainable attitudes and behaviours. However, the limits and barriers to access have become apparent through the data preparation and onward supply phases, and these make it more difficult to fulfil the aim of engaging citizen-users such as community development groups and citizen hacktivists.

The University of Glasgow's Educational Place and Disadvantage research team have primarily presented findings from iMCD in academic forums, but we have also deployed the data to help the wider public better visualise learning inequalities in Glasgow. We have learnt the importance of 'data plumbing', namely the way the datasets are linked and stored together for more participatory access, as the CIM infrastructure advocates, rather than just the infrastructure that holds and the dashboards for accessing the data. We also recognise that potential for such linkage can be limited by legal requirements. In our case, the timing of iMCD's readiness for onward supply coincided with the introduction of the European Union General Data Protection Regulation, and the heightened tension this has created in balancing the desire for open data and the necessity for privacy and data security, and calls for further interdisciplinary collaboration for use of multi-stranded data as an opus for realising urban change.

### 5.3 *Implications for policy and city planning*

The metrics of UNESCO's Learning City Framework were firmly embedded in the design of the iMCD project on the basis that these could benefit from the potential of CIM-based approaches that use diverse data streams and apply interdisciplinary analytical approaches to shape urban policy action. Stojanovsky (2013) describes CIM as a dynamic system of connections, and specifically as interconnected blocks moving dynamically to create the landscapes of urban territories, stating that "the connections between spaces inspire or inhibit contacts and interactions between people... and continuously shape and reshape spaces,

sociabilities and situations" (p.1). Thus, iMCD, like CIM approaches more generally, captures the dynamic relationship of the urban landscape of Glasgow, using diverse open data streams, from education and transportation, sustainability and healthy mobility data, placing findings within the physical confines of urban greenspaces.

CIM offers the opportunity for further consideration of 'data plumbing' of such complex work, embedded at the start of such data-led projects, particularly operationalising levels of data (such as location metrics), and disclosivity/ identifiability of data, prior to collection and linkage. This exemplar illustrates how an integrated data model approach, in line with CIM can be applied not only with advanced planning but through iterative linking of new datasets as they emerge, and how it is possible to bridge disciplines to tackle place-based educational challenges. For instance, such operationalisation in the Learning City field has led to the early development of benchmarking tools for self-evaluation of learning engagement at regional level, directed at TVET (Technical and Vocational Education and Training) colleges in Scotland initially, and at local government level. Using interdisciplinary data and methods offers a place-based view of lifelong learning for different demographic groups of learners. The addition of CIM allows better integration of the physical with the social, and cognitive space inhabited by citizens, prompting urban questions, such as how can we better analyse not only urban spaces, but also within these 'hollow blocks' the social connections and active flows between and within them (Stojanovsky, 2013), demonstrated by our triangulation embedding persons within greenspace.

Therefore, the present triangulated analyses illustrate potential narratives around urban greenspace proximity and use, and its relevance for adult learning engagement in the city, particularly for promoting greater levels of less formal learning. Non-formal adult learning is notoriously difficult to capture, but it is vital for UNESCO's Learning City development, particularly in a post COVID-19 world, where learning has necessarily moved outside classrooms in literal ways. Linkage to more objective measures of active travel around greenspace in the city allows us to recognise real patterns of mobility (and patterns within demographic sub-groups), which may help us develop targeted lifelong learning interventions for citizens, whether they are outdoor learning, online learning or community-led initiatives. The findings illustrate limitations of generalising from any one single strand of data, such as the survey or travel diary, in isolation. Instead, they suggest the need for complex, but well curated and accessible linked data sources, and interdisciplinary (social science, data science and urban planning) teams to make the most of such data streams. Our iMCD household survey is complemented by travel diaries, GPS tracking, lifelogging and social media capture, and offers through its coherence with CIM approaches a link to sensing and evaluating urban change.

We have demonstrated the potential of the iMCD datasets, applied within the little-researched area of adult learning engagement, greenspace and physical mobilities. The data remain available as a linked open resource, allowing further exploratory research into Glasgow as a Learning City. They are particularly useful for developing institutional strategies for

promoting learning outside formal institutions, and, physically, outside classrooms. Such potentially rich multi-level information is being used in educational expansion in Glasgow, and the University of Glasgow, and its ongoing UNESCO Learning City development. Evidence-based capture of data about less formal learning approaches is presently a priority for UNESCO-UIL, especially since the recent formation of an expert panel on Lifewide Learning Metrics (upon which our research team sit). Novel multi-method data capture, linkage to wider urban metrics, and curation for onward supply complements research strategies on less formal learning engagement. Thus, CIM approaches are urgently needed to achieve the Learning Cities metric capture agenda.

### *5.4 Summary of conclusions*

We have demonstrated how iMCD data may uncover city-level patterns of less formal learning engagement for adults, particularly older adults, in relation to greenspace. ***The emerging findings indicate a positive relationship between learning (particularly of less formal types) and greenspace proximity, as well as between learning and active mobilities around the city, although not specifically within greenspace.*** These findings are complemented by GPS mobilities, suggesting that whilst learning-engaged older adults may be more mobile around their cities (Lido *et al.*, 2016), this may not hold for greenspace mobilities specifically.

In sum, the triangulated analyses indicate that greenspace is indeed largely positively related to adult learning engagement overall, and in particular the less formal types of learning, therefore urban and educational planners should consider varied delivery for lifelong learning outside formal classrooms, alongside novel data capture for lifelong learning, including linkage to more objective measures of active mobility patterns (e.g., walking) around urban spaces. Further work may explore links between housing regeneration, as well as urban industrial site regeneration, and city-led outdoor learning opportunities, particularly in areas of deprivation. Such work may promote urban models of active lifelong learning, keeping people engaged with learning and the greenspace around them, in turn keeping citizens more learning-engaged, healthier and more mobile throughout their lives. We therefore see the city of Glasgow as physically structured, but also socially and educationally structured by citizens close to, and making use of, greenspace.

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