Engaging with the Smart City Through Urban Data Games

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Abstract This chapter will explore how gamification can be used to motivate citizens to engage with data about their city. Through two case studies, we aim to show how prompting hands-on experiences with urban data can improve data literacy and ultimately increase citizen participation in urban innovation and the co-creation of smart city apps. The first case study presents a game called 'Turing's Treasure' designed to elicit design features and data from the players for MotionMap, an interactive map that improves the planning of travel through different modes of transport around Milton Keynes, UK. The second case study describes the outcome of several creative and competitive app design sessions that have been conducted with school children in London and Milton Keynes. We conclude by discussing where we think this field is heading in the future and what additional benefits this will bring.

Keywords Gamification · Data · Co-creation · Design · Transport · Smart city · Data literacy

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1 Introduction

Cities are diverse, complex and ever-changing environments. As they evolve, the physical and social infrastructure must adapt to support the increasing population. Cities must ensure that they can continue to provide an adequate supply and fair distribution of fixed resources such as energy and water, as well as effective management of the healthcare, transport and other key services. This is the responsibility of a large number of entities within the city, such as local and national government, private companies, health services and citizens. This chapter will focus on what *data* can tell us about the past, present and future state of a city and how this information can be used to adapt cities and the behaviour of the citizens who live in them to create a more sustainable future. It is increasingly recognised that this *smart city* approach to sustainable development benefits from the input of citizens towards bottom-up innovation, as a complement to top-down city-led initiatives. Citizens, being the ultimate beneficiaries, should co-create the smart technologies in order to ensure their success (Gooch et al. 2015). Citizens have better insight into the problems that they face and they are often contributors and owners of the data that drives smart city applications. The Smart City that is developed through a balance of top-down and bottom-up approaches has the possibility to create technologies that truly address the needs of the people who live and work there.

However, there are barriers to engage citizens with smart city applications and smart city design. Key amongst them is that most citizens are not sufficiently conversant with using and interpreting data to use it as a resource for learning about and modifying their behaviour and environment. In this chapter, we propose how the use of gamification can overcome some of these barriers to citizen engagement with urban data sets, moving them closer to a position where they are fully prepared to be active participants in the co-creation of smart city solutions. Through a mixture of both concrete and envisioned scenarios that have been developed as part of a smart city project called MK:Smart (www.mksmart.org) we will introduce the notion of Urban Data Games—gamified, interactive tasks using urban data sets—and explore different ways in which these might help citizens to engage more meaningfully with their environment through data and thus to change the relationship between the citizen and their smart city.

2 Data in the Smart City

Urban data is increasingly becoming a resource for innovation. It is collected through sensors, smart metres and satellite imagery. It is acquired in various ways via mobile devices, either passively using phone technology to collect data such as location, or being contributed actively by a user, for example through crowdsourcing. The data relates to a large variety of topics, including crime data, weather, energy and water consumption, transport, pollution, council services, health, social and cultural life of the city. There is information about shopping, housing, demographics and other details of the personal lives of the city inhabitants.

Some data can be delivered as live streams which provide real-time indicators of the state of the city system. Access to real-time data allows immediate adaptation to a circumstance, such as re-planning a travel route based on up-to-the-minute traffic information. Historical data can be used to understand what has happened in the past, to discover patterns and trends and to predict the future. This can be used to inform either immediate behaviour, or this can provide insight for longer term planning strategies for city design and smart technologies. For example, analysing patterns of energy consumption across a city can support utility companies to design strategies for reducing energy use during times of peak demand and to predict when these peaks will occur.

Urban data is becoming increasingly open, such that anyone—from citizens to businesses—can equally use the data as a resource both in the design and delivery of innovative smart city applications. However, much of this resource is currently under-utilised, particularly when it comes to citizens designing their own smart city solutions. Both the US and the UK have websites (data.gov and data.gov.uk, respectively) that contain large numbers of data sets that citizens can use and innovate with. However, there is currently a mismatch between the release of data and its use by citizens. At the time of writing, the UK site contains 22,759 data sets but only 378 apps are using that data. The US site contains 159,206 data sets but lists only 76 apps. Currently, the use of data is mainly by developers rather than general citizens, who usually have little awareness of open data platforms.

A number of barriers remain to the widespread adoption and use of Open Data. First, city governments need to have the institutional culture to encourage the release of data and mechanisms in place to ensure the quality and accuracy of the released data (Bertot et al. 2010; Janssen et al. 2012). Second, open data on its own has little intrinsic value; the value is created by its use by citizens. The current situation is that open data systems offer few incentives for users—there is very little promotion of open data systems to the general public, they are hard to use and finding the data you want is not straightforward (Janssen et al. 2012).

The question then is how to effectively engage citizens with data on a deep enough level that they not only understand what data can tell them about the environment in which they live and work, but can start to see the affordances of data for designing solutions to their problems. This is a critical starting point towards citizens actively using and designing with data for their own local problems. In addition to moving towards true bottom-up co-creation in smart cities, the engagement of citizens with data will help them to see the benefits of their own data contribution towards driving the products and services that will ultimately benefit them.

3 Background

Game-based principles such as goals, rewards, challenge and incremental skill-building are often used in non-game scenarios to increase engagement (Iacovides et al. 2011). This is commonly referred to as 'gamification' (Deterding et al. 2011) and is distinguished from serious games, which are games in the more conventional sense but that are used for something other than entertainment. Common examples include games for training, education and stroke rehabilitation. Kapp (2012) identifies that narrative principles are important aspects of games that provide coherence. They engage the player's imagination and are natural way for them to explore and make sense of the world (Schank 1990).

Gamification as a concept is not without its detractors who argue that the use of scoring systems as a motivator (which is only one form of gamification) can improve extrinsic motivation at the cost of intrinsic motivation (e.g. Hecker 2010; Mekler et al. 2013). Nicholson (2012) argues that "the underlying message of these criticisms of gamification is that there are more effective ways than a scoring system to engage users". However, it is generally accepted that whilst gamification may only encourage transient forms of motivation, it is heavily context dependent (Decker and Lawley 2013; Hamari et al. 2014; Schiefele et al. 1992). As such, it is worth considering what previous gamification approaches within an urban context have found.

The use of games and gamification to engage people with their urban surroundings is not a new idea. In one approach, the city streets are turned into a stage for interactive theatre in which actors masquerade as members of the public whilst a small 'audience', far from being passive, must solve clues that lead them on a journey in which they solve mysteries and discover more about the city in the process. One example is 'Accomplice the show' (http://accomplicetheshow.com/), which describes itself as 'adventure theatre' that plays out on the streets of New York. A further example was 'Uncle Roy All Around You', which combined online players with on the street audience in a challenge to find a mysterious figure known as 'Uncle Roy' (Benford et al. 2004). In both cases the clue-solving and narrative game elements are designed to prompt the players to break out of their more usual passive audience role and to participate actively as an integral part of the plot. Without the audience involvement, the play does not end and the audience is left without a resolution. An analysis of audience experience during the play revealed that many people found the experience quite disturbing, in that it elicited a feeling of paranoia. Interestingly, this emotion was regarded by audience members as being a positive part of their gamified theatre experience, contributing towards their entertainment.

Cultural games are not framed as 'theatre', but nevertheless use gamification to engage tourists with the culture of a city. Examples include City Treasure (Botturi et al. 2009), which leads children on a treasure trail around a city, using SMS messaging to mediate interaction and send clues. Goals are tailored to the age of the group doing the hunt, but effectively they lead the children into learning more about the cultural sites in the city. There is a competitive element to engage children, giving points for the types of observations they make. Also aimed at children, O'Munaciedd

(La Guardia et al. 2012) is a treasure hunt in which children explore a city by trying to find a character called O'Munaciedd and grab his hat. Their route and clues are given on a hand-held device. In answering the clues, children also learn something about the culture of the city. In REXPlorer (Ballagas et al. 2008), tourists are wizards, who can cast spell by waving their mobile device in a certain way. By casting a spell, the tourist gets to hear stories related to their current location, as well as being sent on quests. As tourists undertake quests they also take photos. At the end of the game the story of their travels is turned into a blog. The Lost Lab of Professor Millenium (Kuikkaniemi et al. 2014) combined augmented reality navigation techniques with a series of puzzles to prompt young learners to find out more about Helsinki. Hello Lamp Post (http://www.hellolamppost.co.uk/) was a city-wide project in Bristol, UK that ran for two months during 2013. It was designed to prompt playful engagement not with cultural sites, but instead with typically overlooked city locations and street furniture, through the sharing of stories which were submitted via text message and associated with objects via a unique id. This project resulted in 20,000 contributed messages—a success that was repeated when the same approach was used in Austin, Texas, thus demonstrating the potential of a playful approach to engage a large number of people with their environment.

An alternative use of gamification within a city is in bringing communities together. For example, the ZWERM system (Coenen et al. 2013, 2014) was designed to increase the sense of community in two neighbourhoods in Ghent. The two neighbourhoods were competing to gather the most points. Citizens could gain points by 'checking in' by placing an RFID card on a reader on a hollow tree in a public space within the neighbourhood. More points were earned if two players checked-in together (encouraging players to talk to their neighbours). The ZWERM system was relatively successful—277 people took part and the results of the study indicate that the game was successful at increasing social capital. However, whilst the authors present a description of the living labs process used to generate the game, they offer no insight into the robustness of the methodology or its strengths and weaknesses. In City Game (Games: at field of view 2012), players use Lego-like blocks and follow a set of rules to collaboratively develop a city plan. The goal for City Game is to provide insight to city planners about the needs of different communities, as represented by the players and for the players to come to understand more about the conflicts and constraints of city planning. However, City Game is dissociated from the real-life urban context. Another example of bringing communities together through play is the project 'Hippokampos in the Grey Matter' (2012) by the women's art and technology group MzTEK, in collaboration with designer Pollie Barden. This saw women in Athens participate in a workshop in which they together designed a game that was then played by members of the public the following day. The aim was for people to reflect on their physical environment whilst playing, but also to encourage more women to engage with creative technology practices through the involvement of MzTEK.

Through the above, we have provided some examples of how games can engage citizens with the urban environment. However, these commonly lack a focus on empowering the players to understand better how to change and adapt their environment, or to change their own behaviour to better fit with the environment. We propose that engaging citizens with data about their environment can help in this transition. If citizens understand what the data tells them about the past, the present and how this can predict the future, then citizens gain insight into both what needs to change and potentially how to bring that change about. In the exhibition ‘a conversation between trees’ (Jacobs et al. 2013) art was used to prompt deeper reflection on climate change data. Whilst not framed as a ‘game’, the experience was designed, much like a narrative, to elicit an emotional response from the audience, such that they would reach better clarity about their own perspective on the topic which would be more likely to lead to behaviour change. Another example, ‘Summer School Data Explorers’ (2015), combined data with art through workshops led by technology education company Codasign. School children in transition year (about to begin secondary education) collected their own environmental data using sensors and Raspberry Pis within the Queen Elizabeth Olympic Park, London, UK and used their artistic skills to produce visual analyses of their data. This was turned into a site-specific piece of art by designer Stefanie Posavec, reflecting the findings as a group. In these cases, interaction with the environment is not only direct but is also mediated through the lens of the data and the interpretations (both analytical and artistic) that are made about it.

Urban policy making is increasingly influenced by data, as are patterns of behaviour. But technologist’s conceptions of data as neutral and objective are fictions; data are inherently partial, selective and representative and the criteria used in their capture have consequence (Kitchin 2014a). Thus, the smart city agenda can become an arena of collaborative argumentation, helping to identify what the issues are, how they are understood and what possibilities there are for action (drawing on Healey (1997) about participatory discursive democracy). Such an approach can be achieved in a variety of ways, and opens up a role for urban data games.

Games can play an important role in smart city developments, but that role depends on what type of smart city is envisaged (Kitchin 2014b). If a smart city is one where businesses and government organisations develop smart city systems for their purposes of efficient management and control, then gaming elements may be used to ensure the understanding of citizens. A more interactive approach is to use serious games to educate citizens’ perspectives on information to inform their choices as consumers. A further stage is where, through gamified approaches, citizens take an active role in managing and in co-creating the smart systems themselves and collect and use data which is meaningful to them. Gamification in this latter context is not just about educating citizens about using and valuing smart city big data systems, but in them being empowered to have genuine input into the design of those systems. This is about using smart city systems for democratisation. These approaches to urban games are not mutually exclusive, and elements of each have been explored in the context of a smart city project taking place in Milton Keynes, a town with a population of 260,000 located in the South-east of England.

The vision behind the MK:Smart programme is built around a smart city concept that seeks city efficiency through a focus on using ICT for democratisation.

MK:Smart is a £16 million smart city initiative, co-funded by the Higher Education Council for England, taking place in Milton Keynes between 2014 and 2017 (MK:Smart 2016).

4 Urban Data Games

The remainder of this chapter will explore two quite different scenarios in which gamification is used to prompt user engagement with urban data in the co-creation of smart city technologies. The first is in the co-creation of MotionMap to create a shared resource to improve travel planning around Milton Keynes, UK. The second is in a gamified task in which young students design smart city applications as part of an initiative to improve data literacy of school leavers in the U.K.

We define these as Urban Data Games, which use one or more aspects of gaming such as narrative, challenge or reward as a mechanism to prompt engagement with an urban data set in the co-creation of smart city technologies. Within an Urban Data Game, the gamification principles are designed to encourage the user to engage in behaviours that are closely aligned with the desired outcomes. For example, if the goal is to encourage users to engage with a smart city app, or to contribute data to an app, a gamified approach could be to set a goal that is only achievable through these behaviours. In designing an Urban Data Game it is therefore important to be clear about (1) what are the intended outcomes, independent of the game (2) what will motivate the user towards those outcomes. Gaming elements should be most focused on activities that users would not naturally be motivated to undertake, either those that they find difficult or those that they find mundane.

4.1 MotionMap

Within the MK:Smart programme, a smart transport initiative called MotionMap is currently (2016) in development. MotionMap is intended to demonstrate the concept of 'Cloud Enabled Mobility', an app that connects users with information and other cloud-based services to enable informed transport decisions. A large number of mobility information apps already exist, varying from driver GPS guidance to parking availability, bus and rail information, bicycle sharing and taxi booking, among many others. Many of these are isolated supplier-led apps, some seek to integrate travel information across a city (e.g. Citymapper), but they often do not provide real-time data and are a centralised approach that provides data to users that providers consider they should have, rather than information that users have had a role in specifying as meeting their needs.

The approach in MotionMap will go beyond the information provided by existing travel apps, in that it will continuously describe the real-time movements of people and vehicles across the city, providing embedded timetables and estimates of conges-

Fig. 1 A MotionMap mock-up

tion and crowd density in different parts of the city. It is also envisaged as a platform whose design and operation incorporates the needs of its community. It will also be a platform on which community groups, businesses and other organisations can develop their own applications. Figure 1 shows a mock-up of MotionMap.

To bridge the gap between this abstract concept and the specifics of its implementation, a key desire in MK:Smart is to engage citizens in the co-creation of solutions using the MotionMap platform. The intention is also to design the system to allow users to actively contribute relevant data in order to increase its value to all. Some of the information required for smart transport can be generated automatically, through feeds from existing databases and traffic sensors, etc. However, the system provides greater legitimacy and informational richness if users contribute information that is relevant to them and their peers (for example, reporting traffic jams, rough surfaces and faults on cycleways or tardy bus services).

Citizen workshops have taken place as part of the MK:Smart programme, including the use of illustrative non-functional prototypes and mock-ups of MotionMap to foster discussions in user workshops. Here participants were asked to discuss the features of MotionMap that they would value. The semi-structured discussions prompted by the prototypes were messy, with participants talking about their concerns, existing practices and ways in which smarter transport information might improve their quality of life or make their transport more sustainable. This information was relayed to the software developers, shaping the features of the app. As the functionality gradually increased, new prototypes and new scenarios could be introduced into the conversation. This iterative process continued until there was sufficient functionality to transition from the workshops into an approach based on urban games.

4.1.1 Urban Games for Smart Transport: The Case of Waze

The urban gaming strategy pursued by the MotionMap team was based on the study of similar smart transport projects, deployed on a commercial scale, and which demonstrated that games could be used to foster user engagement and facilitate user-centric design. Inspiration was drawn from several games and serious gaming applications [including Open Street Map's mapping parties (Hristova et al. 2013), Citymapper's provision of estimates for jetpack users, Strava's virtual 'King of the Mountain' competitions for cycle users (Smith 2015)], but particularly from a motorist app, Waze.

Waze was founded in 2008 in Israel. Its flagship product is a GPS-based app for driving navigation with turn-by-turn instructions that adjust to traffic in real time, suggesting alternative routes for users to get around congested areas. This has subsequently been developed to provide other user benefits, including ridesharing matches. Data is generated entirely by Waze users themselves, meaning that a community can make it effective without linking to other GPS information (Waze 2016). It is an entirely self-contained user data generation and sharing system. This crowd-sourced design does not conform to the usual smart transport model built around centralised infrastructure instrumentation; Waze is smart transport of a different type, and a very successful one. Waze has expanded globally to have a user base of approximately 50 million people worldwide. Its approach attracted the attention of Google who, in June 2013 bought Waze for $966 million.

The challenge identified by Waze's founders was that of getting to critical mass. Widespread adoption will not take place unless the app can provide something valuable to early users. However, offering a service of actual practical value can be difficult in the early stages of diffusion of an urban sensing system. In response, the development model followed by Waze (and adopted by MotionMap) includes gaming as a crucial feature. This model consists of four stages

- Build
- Play
- Provide value
- Achieve critical mass

The first stage involves building a minimal base system (e.g. providing a map of the basic road grid). At this stage, it is not completely functional, but there is enough for early adopters to play with, and to demonstrate the application's potential. Thus, ludic value can be delivered through the inclusion of actual game-like elements, but also by making a system that makes user contributions rewarding and that is fun to tinker with. Eisnor (2011) summarised this as " You can't deliver a lot of value, but people see that it is working and growing". If this 'playful' stage attracts the attention of a sufficient number of potential users, they act as value co-creators. The system can then grow to the point where it can provide practical value. It is in this stage of the approach that the service starts to become dependable and achieves critical mass.

When Waze is introduced in a new city and insufficient data is available, users driving on an unmapped road can transform the application into a real-world version of a video game with their on-screen avatar transforming into a 'Pac-Man' eating power pellets and other rewards whilst routing information is automatically collected in the background. Whilst more seriously-minded users are free to ignore this game-like aspect of the application, Waze reports that 8–12 % of the users will go out of their way to earn a virtual cupcake. Through the increased efforts of those 12 % of gamers, sufficient data can be collected to deliver practical functionality to the complete user base. Waze does not only use gamification as a development tool, but in the design of its interfaces with users, with engaging playful features that support the overall user-focused approach.

4.1.2 MotionMap Games

The urban gaming strategy for MotionMap relied on playful value to foster early engagement, before practical value could be delivered. Early functionality of MotionMap had a very limited coverage, but did include traffic sensing for a limited number of roads, there were a few car parking areas that had sensors indicating if they were occupied or not, and real-time bus scheduling information was available for some stops. This patchy sensing data was made available by several teams of technical developers as they deployed proofs of concept for different monitoring solutions. These could not offer practical value, but they provided enough glimpses of the city for a virtual treasure hunt to be designed. This was a small-scale game, linked to the Freshers' Week for full-time Open University Ph.D. students held on the OU campus in Milton Keynes in October 2015. Figure 2 shows some publicity material for this hunt.

This virtual treasure hunt was entitled *Turing's Treasure*. It weaved the limited data available into a story about Alan Turing, who was a computing pioneer based on the secret Second World War code-breaking centre at Bletchley Park. Turing actually buried and subsequently lost a cache of silver somewhere in Milton Keynes, so this story was used to provide play value for a very early stage of MotionMap that provided little practical value at all. MotionMap made this limited data from sensors available visually, but also in numerical format. The game used this numerical information to provide clues allowing the gamers to solve a cryptogram identifying the virtual location of the treasure.

Fig. 2 Publicity for Turing's Treasure

The treasure hunt had a duration of one week, with daily clues and challenges which required interaction with the transport data made available through the online prototype MotionMap. Figure 3 shows the winners receiving their prizes. The interaction of the players with the game was tracked through online metrics, through their responses to the challenges and, most importantly, by inviting direct feedback. The game encouraged sustained interaction, which created awareness of its capabilities and limitations, and reflection about potential practical applications. The literature on interactive systems design suggests that prototypes can be used as 'straw men' to elicit customer input during requirements gathering, providing a target point for discussion and a target for criticism (Rudd et al. 1996). In the case of *Turing's Treasure*, the introduction of playful elements into the prototype made it possible to sustain this process for a week, in contrast to more traditional user workshops where the duration is limited to a few hours.

Some of the feedback produced by this process was related to minor technical issues and bug reports were raised by users, but some users sent detailed letters with suggestions and features they would like to see in future iterations of the game, or even volunteered to contribute to development efforts. Whilst users do not expect to use the current version of MotionMap for practical purposes, they described features and applications they would like to see. Interacting with the game contributed to envisioning of the complete product, and to proposals about features that would be of interest.

Insights from the iterative design process facilitated by prototypes and games are contributing to a gradual re-definition of the scope of cloud-enabled mobility. MotionMap was initially designed with car users in mind. Features most emphasised in the game and in the mock-ups used in the workshops targeted drivers (for example, with questions in the virtual treasure hunt involving the use of parking sensors). However, users were more interested in features related to alternative forms of transport.

The walking and cycling features of MotionMap played a limited role in the game, but attracted the attention of users. Whilst car users in Milton Keynes were found to

Fig. 3 Awarding the prizes to the two games winners

be generally satisfied, pedestrians and cyclists declared that some smart support would be welcome. Users were interested in maps and navigation instructions, but also in road reports generated through automated and crowdsourcing methods. For example, the accelerometers that are integrated with some smartphones can be used to produce automatic reports regarding bad surfaces, steep gradients and unexpected sharp bends in cycleways. There was interest in complementing this automatically generated data by crowdsourcing information about hazards like glass on the cycleways, areas with insufficient illumination, or flooded underpasses. By providing advance notice of the hazards, users can plan alternative routes, or ensure that they are riding at a safe speed when they approach problematic sections of the roads.

Public transport users were also enthusiastic about MotionMap. Through their interactions with the game and the prototypes they envisioned and requested additional functions that were not foreseen originally, but that could be supported with the smart city infrastructure. Particularly, they were interested in using the sensing systems for providing their own crowd-sourced, real-time reports about the location of buses. One key aspect to emerge from the workshops and discussions was that user crowd-sourced monitoring activity would make transport providers more accountable. This, in effect, would counteract the existing disempowering relationship between bus users and service providers. At the moment, transport providers are the sole gatekeepers of information, and there is limited accountability for delays or interruptions to the service. Shifting this relationship so that users become information generators and holders is valued and would be a radical step, which will be exploring in the next iteration of the game.

4.1.3 Lessons Learned

By playing a game, when only limited MotionMap functionality had been developed narrowed the scope of this game, but made it possible to integrate users into the design process early, before major design decisions had been set in stone. This early inclusion through the gamification of user testing provided several lessons

1. Some lessons were purely technical. The game tested the smart city infrastructure, and its capability to keep MotionMap and all the feeds running and accessible to several users on a variety of systems and browsers;
2. It tested the suitability of using a game as a vehicle for creating awareness and fostering user engagement;
3. The game provided feedback about usability, and prompted reflection not only about the MotionMap, but also about its potential applications. Because this feedback was received early in the development process, it could have a meaningful impact on the final version of the MotionMap app.

These results fed into an MK:Smart workshop considering how gaming approaches could be further used for MotionMap and also applied in the development of the MK:Smart's other workstreams. One key conclusion was that the role of gaming changes as a smart city initiative develops. There should not be a single function of urban games but, as in Waze and other examples, there need to be layers of gaming that

(a) Provide early stage developmental feedback
(b) Helps users to envision and build their own applications based on the product
(c) Encourages early stage user engagement
(d) Supports the development of a community of champions
(e) Provides engagement with the final product
(f) Provides rewards to users who engage in socially beneficial behaviours.

These different styles and aspects of serious gaming and gamification are not necessarily sequential, but need to be present for the needs of different users at different times. For MotionMap, serious gaming activities initially targeted points (a) and (b), using urban games as part of a long-term strategy of iterative prototype-based co-creation. In order to engage a growing number of citizens into this process, we are now moving to focus on functions (c) and (d) with gamification elements to be incorporated in the design of the app features.

4.2 Urban Data School

There are a number of barriers to citizen participation in the planning and design of sustainable 'smart city' solutions. One key limiting factor is that the majority of citizens lack practical experience in handling and using complex data sets in the design of physical products and services. Thus, currently, the expert use of data is the preserve of businesses and government organisations, who have more expertise to draw on for utilising this data. We need to find ways to engage public with the urban design process and at the same time improve their knowledge and conceptual understanding of the relationship between data produced by people as they live and move around the city and the physical urban environment they inhabit.

The Urban Data School (UDS) is an initiative aimed at delivering content around complex, urban data sets to improve data literacy of school leavers. A number of creative app design sessions have been conducted as part of the UDS. These are designed to give students experience of imagining how data can be used as part of smart city innovation. In the app session the students are set up into competitive teams and given a challenge to design the best app which uses some collected form of data and which can solve a problem in their local area. They are the only activities in the Urban Data School which do not use real data sets—instead the students must use their imagination to think what sort of data they could use, how it would be collected and what this might be able to tell them. Students are prompted to design non-standard visualisations of this data into their app design. The appathon is a form of event-based learning, based on principles of challenge-based learning (Johnson et al. 2009) which puts people under time pressure. Often a collaborative learning experience, participants are provided with some information and goals prior to the event in order to prepare, i.e. organise a team, define roles for members based on expertise and identify and address skills gaps. Thus, the appathon aims to use game-based principles of challenge and reward to motivate the students to perform well in the task, despite many of the concepts around smart data, complex data and visualisations being new to them.

Appathon 1 Occurred during a regular classroom session in a Milton Keynes school. A total of 17, year 9 (age 13–14) students, in advanced science classes, participated in three sessions over a three-week period. The first two sessions were designed around the use of complex data obtained from the wider MK:Smart project. These sessions encouraged the students to explore home energy consumption and solar generation of households in Milton Keynes by analysing smart metre data and an aerial photography map of the city, visualising potential solar energy production for the different rooftops. The final session was the app design session, which occurred during a 2.5 h classroom session with no break. Students were divided into four groups, each of which produced a unique app design.

Appathon 2 Occurred as part of an initiative that provides additional learning opportunities for young students from several schools, in the form of weekend tutorial and workshop events. In this session a total of 38 students, aged 15–16 were given a tutorial on big data and how it is used in smart city applications. Following this, the students took part in one of two app design sessions, each of which took 1 h and 25 min. There were 18 students in the first session, who divided themselves into 5 groups and 20 in the second session who divided themselves into 3 larger groups.

4.2.1 Session Formats

Both appathon's began with verbal and written instructions for the participants. In both sessions students were instructed to design an app to tackle an urban problem. They were told it was a timed session, that they should work in groups and that at the end of the session they would pitch their idea. The winning group would be chosen by a panel based on the following criteria: (a) Quality of pitch, (b) Technical feasibility of the app, (c) Creativity of design, (d) Use of data and data visualisations and (e) Innovation. These criteria were designed to get the students thinking broadly and creatively about how they could design an app which would provide intelligence with real impact. Students were also provided with a list of prompts, which encouraged them to think about: 1. Who were the app users? 2. What would the interface look like? 3. Why would people use the app? 4. What data would be used and how would it be visualised? 5. How would people use the app?

The hand-out given to the groups in Appathon 2 included additional instructions to sketch the interface, as well as an example design. They were also given four additional real-life examples of urban apps based on data. In Appathon 1 (the earlier session) the groups were also asked to sketch the interface, but this instruction was given verbally.

Students were provided with flipchart paper and coloured markers. In Appathon 1, the project teams were supported both by the regular classroom teacher and two researchers from the UDS initiative. In Appathon 2, the groups were supported both by helpers who often attended the weekend sessions and were known to the students, and three UDS researchers.

The appathon challenges were designed foremost as an opportunity for students to learn more about designing smart city apps, gain better understanding of using data within design and to develop critical thinking skills. Therefore, it was necessary to offer students appropriate support to achieve this. It was also an opportunity for us to assess the competencies of the students. Consequently, it was decided that one researcher who was present at both sessions would circulate between the teams, offering support over the course of the task. They provided the same set-prompts to workgroups in both appathons, focusing on the use of data as this was key to the theme of the appathon and was identified as the most unfamiliar aspect of the task for the students. The groups were given 10–15 min to generate their initial ideas. The researcher then visited each group in turn to listen to and support their ideas and to suggest improvements. This was intended to encourage the participants to focus specifically on the use of data and the analysis of this data within their app. All groups had, at this point, identified what data they would collect and how this would drive their app's functions. The researcher prompted each group to think about how a 'smart city' analysis *across* their data sets could give their app broader scope and more powerful functionality. The researcher gave examples related to the student's own proposed data. In cases where a group was already proposing a solution in which collected data was analysed, the researcher prompted them instead to think of more novel ways to collect data. Towards the end of each session, the students were encouraged to finalise their pitch. They presented their ideas and a winner was chosen using the criteria stated above.

5 Findings

It was clear from observing the challenges that the students were engaged with the task. Each group worked together and managed to produce and present a unique app design within the time limit. Across both the appathons, with both the younger and older age group, students needed the most support and prompting in thinking about how the data they proposed to collect could be analysed to yield the most insight across the geographical region or population represented through the collective data. Whilst the app designs were never intended to be working products, it was apparent that students were thinking in terms of the brief and the majority of designs were both feasible and applicable to a real-life problem that they had identified. The app designs consisted of the following (appathon number is shown in brackets):

1. Identify Wildlife—identify wildlife from an uploaded photo (1)
2. Walking Wardrobe—show trending clothing items in the local area (1)
3. Barcode Scanner—scan your recycling and earn points (1)
4. Baby Steps—timely advice for mothers on when to tend to their baby (1)
5. Oldies—social media app for older people to connect with each other (2)
6. Hotspot—show busyness of nearby tube stations
7. Y2K Youth—find events for teenagers (2)
8. Leisure Time—meet like-minded people in your area within hours (2)
9. Taxis on Demand—match people to a nearby taxi with appropriate number of seats (2)
10. Guide Me—find safe route for people based on declared disability (2)
11. Grocery Genie—keep track of what people buy (2)
12. NHS—for making doctors appointments (2)

The Hotspot app is shown in Fig. 4. Since the appathon revealed that students had most difficulty in aspects of the challenge related to planning analyses across their ‘collected’ data, some new research is being planned which will focus on whether a more tangible, playful, interaction with data can support students better in this activity than the purely ‘mind-based’ planning within the appathon task. A tangible map will be created upon which students can plan where and how to collect different types of data and get feedback in real time. The aim is to framework a learning experience which prompts pupils to move away from considering collected data as simply a localised data source, towards considering it as a spatially located source with a temporal dimension. It is hoped that ultimately this will lead learners to understand how multiple data points are related spatially and temporally and what insights can be found by utilising this information.

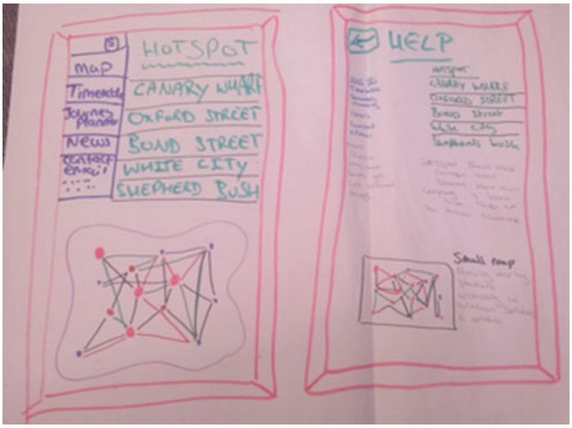

Fig. 4 The Hotspot app design

Finally, future work within the Urban Data School will investigate the use of alternative urban data games for engaging the students. One of these will be an *Eco-puzzle* which would be delivered as an 'escape the room' type challenge. In this puzzle participants would be provided with multiple, partially simulated data sets where some of the data provides clues to a recent disaster. The goal is to find out what has happened in the shortest time and present a compelling justification, backed by data visualisation and analysis. Participants must query the data sets and narrow down the time frame for an event. Data will include sensor readings that show an anomaly, simulated Twitter data of some eye-witness accounts, traffic data showing travel disruption, police reports or air pollution measurements. The goal is to apply data interpretation, analysis and visualisation skills to first identify an anomaly in one of the data sets which gives a narrative *setting* (a time and place) for the event. This is used to frame further queries across other data sets and build evidence about what occurred. Hints can be given, as there is a single, verifiable, solution but the sources of data used to evidence it can differ. Therefore, the competition may be judged on fastest or best solution, also taking into account the number of hints used.

6 Discussion and Conclusions

The city is perhaps the arena where data has its greatest utility. In places where there are high concentrations of people, information becomes richer and more prevalent. In parallel, the potential for the information to be used for social, political and environmental interventions is greater. The projects outlined above are uncovering how playing with data in the city can make the raw information a fun and meaningful resource for design and bring data handling to a larger audience.

Over the course of this chapter, we have overviewed a number of projects that handle the concepts of data and gamification in the city. Two projects, the *Turings' Treasure Hunt* and the *Urban Data School* have looked to combine these two factors.

These two projects make the participants confront data in the city from different perspectives and at different levels of abstraction. The MotionMap asks participants to be present in the city and engage with data as physical agents, ‘on the ground’. The urban data school asks the participants to take a step back from the action and consider the state of the data in the city as an overseer. In spite of the difference in their approaches, they both lead to the participants reflecting upon the prosperity of their city and their fellow citizens and thinking creatively about how they can exploit the information to solve problems. The treasure hunt challenge made the participants reflect through experience. They were made to consider how the physical features of their city and their movement across it could be encoded into data and used as a resource for design as they explored the city themselves. The urban data school, meanwhile, took the participants on a journey of more internal exploration. They were made to draw upon their conceptual understanding of the city’s systems and processes and reflect upon how they can use data to solve its problems without engaging with it physically.

In both cases, the data is made to seem like more than a crude set of numbers. It is given a colour and form through its relationship, with the physical environment and the pixels of an app. The gamified narrative, meanwhile, empowers the participants and makes them feel like they can have an impact upon real-world problems. This can have benefits where bottom-up design is concerned. It appears that by setting the participants against each other as competitors they are motivated to engage with low fidelity technology designs like Waze and the MotionMap for longer periods of time and have the confidence to voluntarily contribute their opinions on how the systems can be improved. In the case of the Urban Data School, the competition format makes the participants more willing to think abstractly about how different sources of information can be pulled together across a geographical region to provide insights on a city issue.

6.1 Future Work

We have only touched the surface where urban data games are concerned and there is plenty of scope for future research in this area. One of the key outcomes of urban data games is education. The engagement of the participants with data sources clearly has the potential to be a source of learning, in terms of creativity, real-world problems and data literacy itself. Gamification could be a great tool for overcoming the attrition rates that can befall other number-based topics of study (Seymour 1992). However, as discussed, it is important to not let the narrative of the game dilute the subject of study to the point where the participants are no longer getting any of the core learning. There is a specific risk that designers might be tempted to make the learning experience too superficial in the context of urban data games because of the scale and complexity of the problems that are being confronted. Future research should establish how many layers of narrative can be added to the learning experience before it is tarnished.

Another key area for future research is to try and better understand the how to engage different target audiences. The MotionMap and appathon designs were tested on specific social groups (Ph.D. students and school children), who may be more motivated to engage with technology and learning tasks than others. It would be beneficial to start building a framework to outline what kinds of data games should be used in different situations for the broader spectrum of society. One of our immediate objectives is to create urban data games that are targeted at specific groups who play a key role in the running of the city (e.g. bus drivers, policemen, councillors). These games are intended as a stimulus for the ideation of new services. Through these design sessions we aim to gain a first insight into whether urban data games can solve some more obscure city problems and engage *harder to reach* social groups. Ultimately, by tapping into the intrinsic human need to play, compete and learn we hope to cross social boundaries and bring about positive, systemic change in the areas where traditional forms of citizen engagement have failed to do so.

> I have wrought my simple plan
> If I give one hour of joy
> To the boy who's half a man,
> Or the man who's half a boy.
> (Arthur Conan Doyle)

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