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Educating the smart city: Schooling smart citizens through computational urbanism

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Abstract

Coupled with the 'smart city', the idea of the 'smart school' is emerging in imaginings of the future of education. Various commercial, governmental and civil society organizations now envisage education as a highly coded, software-mediated and data-driven social institution. Such spaces are to be governed through computational processes written in computer code and tracked through big data. In an original analysis of developments from commercial, governmental and civil society sectors, the article examines two interrelated dimensions of an emerging smart schools imaginary: (1) the constant flows of digital data that smart schools depend on and the mobilization of analytics that enable student data to be used to anticipate and shape their behaviours; and (2) the ways that young people are educated to become 'computational operatives' who must 'learn to code' in order to become 'smart citizens' in the governance of the smart city. These developments constitute an emerging educational space fabricated from intersecting standards, technologies, discourses and social actors, all infused with the aspirations of technical experts to govern the city at a distance through both monitoring young people as 'data objects' and schooling them as active 'computational citizens' with the responsibility to compute the future of the city.

Keywords

Citizens, code, computational urbanism, data, governance, smart city, sociotechnical imaginary

Computer code and digital data have become powerful influences in the social organization and governance of education. At the same time, cities are being reconceived as composed of code, driven by data, and made 'smart', 'programmable' or even 'sentient' (Kitchin, 2011; Thrift, 2014). At the intersection of these developments, a range of commercial, governmental and civil society organizations is now engaging in a reimagining of education for the smart city. By tracing key technical developments and related discourses, the article examines the emergence of 'smart schools' that are currently in-the-making – fabricated educational spaces that are to be enacted by an assemblage of coded technologies and data practices (performed by technical experts) and supported by the production of discursive imaginings that are intended to school individuals' capacities, skills and literacies to participate in the smart city itself.

The article contributes two original lines of critical analysis: (1) by tracing how commercial vendors such as IBM and Microsoft are extending their global smart cities programs into a reimagining and reconfiguration of schools as data-based sites of real-time monitoring and measurement, where students are increasingly treated as 'data objects' whose actions can be altered through programming the environment; and (2) by examining how governmental and civil society organizations are working within local smart cities initiatives to develop young people's capacities as active 'smart citizens', with the technical data skills to contribute to computational urbanism by participating in 'civic coding' on behalf of the city. These features constitute an emerging educational infrastructure of intersecting

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standards, technologies, discourses and social actors, all infused with the aspirations of technical experts to govern the city at a distance through monitoring and manipulating young people as data objects, while also schooling them to act as active computational citizens with the responsibility to compute the future of the city. The novel claim advanced in the article is that education is being positioned as an urban laboratory in which imaginaries of the smart city are being made attainable in experimental form. For advocates of future city visions, the attainability of more data-driven and computational forms of urban governance appears to depend on educating the smart city and the citizens that inhabit its computational dynamics and its associated forms of conduct.

The design of technical innovation always assumes the kind of people expected to use technologies and therefore to some degree 'invents' the user according to the assumptions and politics of technical experts (Ensmenger, 2010). Likewise, as technical innovations on a grand scale, the design of smart cities by particular technical experts assumes and invents the kinds of citizens expected to live and learn in them. Smart schools are imagined educational institutions that will contribute to urban governance by shaping citizens' capacities to contribute to the management and optimization of the future of the city. The article considers current and emerging developments around schooling in smart cities as a particular social and technical instantiation of the contemporary fascination with big data that might itself play a role in 'the formation of other social, political and cultural developments of different types' (Beer, 2015: 11). Reimagined as programmable and data-driven platforms, peopled by young big data analysts and computational operatives, smart schools are to play a role in the formation of new types of computational urban governance.

Of course, the role of data in the organization, management and governance of educational institutions, spaces and practices pre-dates both big data and smart cities (Lawn, 2013). However, with the emergence of big data specifically, new kinds of data-based software and its underlying standards, code and algorithmic procedures are increasingly being inserted into the administrative and political infrastructure of education systems (Williamson, 2015a). Commercial companies have quickly responded to the ostensible potential of big data technologies and practices for new modes of educational governance. For example, the commercial education vendor Pearson Education has established a Center for Digital Data, Analytics, and Adaptive Learning which envisions education systems where 'teaching and learning becomes digital' and 'data will be available not just from once-a-year tests, but also from the wide-ranging daily activities of individual students' (Williamson, 2016).

Likewise, the authors of *Learning with Big Data: The Future of Education* (Mayer-Schönberger and Cukier, 2014) imagine that big data will 'reshape learning' through 'datafying the learning process' in three significant ways: through real-time feedback on online courses and e-textbooks that can 'learn' from how they are used and 'talk back' to the teacher; individualization and personalization of the educational experience through adaptive learning systems that enable materials to be tailored to each student's individual needs through automated real-time analysis; and probabilistic predictions generated through data analytics that are able to harvest data from students' actions, learn from them and generate predictions of individual students' probable future performances. The authors imagine school as a 'data platform' where the real-time 'datafication' of the individual is becoming the 'cornerstone of a big-data ecosystem' and in which 'educational materials will be algorithmically customized' and 'constantly improved' (Mayer-Schönberger and Cukier, 2014). As Finn (2015) notes, schools are becoming more like 'data centres' where teachers and students are treated as 'data producers'.

These imaginings of schools as platforms for the collection and calculation of big data are being developed with particular enthusiasm in many smart city programs, where themes such as 'smart education' and 'smart learning' are emerging. Various organizations and actors have begun to produce materials envisaging education as a smart social institution situated in new digitally mediated urban infrastructures. For example, IBM has launched a 'Smarter Education' program as part of its global 'Smart Cities' agenda (analysed in more detail later), while Microsoft's CityNext initiative features an 'Educated Cities' program premised on an assumed interdependence between the future city and the school:

> While many cities are already well on their way toward modernizing their technology infrastructures, they also need to respond to today's most important education trends.... To thrive, cities need to provide access to powerful learning devices, tools, and apps that empower education. (Microsoft CityNext, 2014: 5–6)

The issue, then, is not just about the reshaping of the school by tracking and monitoring students as data objects but about educating the smart city itself by enabling students to become active citizens who can participate in the practices and performance of programmable urban processes. In this sense, education is a powerful social institution for the realization of smart cities imaginaries – both as a site for prototyping and normalizing big data techniques of population monitoring among young people and as a site for reskilling them as data operatives – though its role has been empirically neglected and critically under-conceptualized in both educational and smart cities research to date.

By analysing documents and organizations that promote a reconfiguration of education in relation to smart cities, this article contributes an original, critical analysis of how education is being positioned as a laboratory space for the enactment of big data practices and as a social mechanism for the production of 'smart citizens' who can participate actively and productively in the big data dynamics of the smart city. Just as the design of any technology assumes a user, and therefore at least partly configures the user (Woolgar, 1991), and education is always involved in the production of subjectivities to inhabit particular socially prescribed forms of conduct (Foucault, 2007), the design of the smart city assumes a particular kind of smart citizen, a citizen who must therefore be educated for participation in its computational circuits.

Conceptualizing smart cities

In the fields of architecture, urban science and computational urbanism, increasing attention has turned in recent years to the emergence of 'smart cities', 'adaptive cities' and 'future cities' that are augmented with 'big data', 'sensor networks', 'ubiquitous computing', 'coded infrastructures' and other computationally programmable processes and software-supported data practices scripted in code (e.g., Batty, 2013; Shepard, 2011; Townsend, 2013; Verebes, 2014). Commercial computing firms have launched projects promoting their products for smart cities, including IBM, Cisco, Intel, Siemens and Microsoft, many linked to huge urban projects building new smart cities from the ground up, such as Songdo in South Korea, PlanIT Valley in Portugal and Masdar in Abu Dhabi, but much more commonly in the 'upgrading' of existing urban infrastructure (Shelton et al., 2014). Large funding grants have been awarded to research on digital urban infrastructures in the field of computational urbanism, many based at new research centres at universities, while political initiatives have made the future of cities into a subject of governmental attention (Government Office for Science, 2015). There is even an international smart cities standard stipulated by the International Organization for Standardization, ISO 37120:2014, to enable cities to measure and compare their performance and learn 'best practices' from one another in terms of indicators for planning, infrastructures, governance, economy and education, amongst others (ISO, 2014). Commercial smart cities vendors have become key actors in the enactment of such standards by providing technological infrastructures and instruments that make cities measurable, comparable and practicable.

In response to the increasingly standardized model of the smart city, urban research from geographical and sociological perspectives has sought to critique it in terms of being market-based, technocratic, surveillant, solutionist, militaristic and reproductive of power asymmetries (e.g., Kitchin, 2014b). Critically reviewing the smart cities literature, Gabrys (2014) characterizes them as urban spaces enabled by automated infrastructures, equipped with networked digital sensors and ubiquitous computing, that provide augmented experiences through mobile devices, that mobilize the capture and analysis of big data from urban processes in real time and as spaces in which citizens are positioned as 'data points' and 'data-gathering nodes'. The smart city is an urban environment governed by the capacities of coded devices and infrastructures, structured and supported 'line by line, algorithm by algorithm, program by program', 'by code using data as fuel' (Thrift, 2014: 10), without which it would cease to function as planned. To some degree, smart cities are cities that 'think of us' (Crang and Graham, 2007: 792), with some form of sentience and reflexive awareness, along with some ability to learn and to transform themselves.

As this brief summary indicates, the standardized smart city constitutes a re-imagining of the computational future of urban environments, in which practices of urban governance, such as traffic management, environmental monitoring and surveillance, are delegated to a dense infrastructural mosaic of sensor networks, data collection technologies and algorithm-driven forms of analysis, all of it refracted through global urban standards and enacted by the work of programmers and the execution of the code they script. As the fundamentally performative layer of software that does work in the world, code has become a key source of social power. It projects the 'secondary agency' of programmers into everyday life (Mackenzie, 2006), with the consequence that smart cities are thus becoming 'programmable environments' where software code alters how aspects of city life are conducted:

> The programming of environments... is generative of political techniques for governing everyday ways of life, where urban processes, citizen engagements, and governance unfold through the spatial and temporal networks of sensors, algorithms, databases and mobile platforms that constitute the environments of smart cities. (Gabrys, 2014: 44)

The programmable environments of the smart city are infused with the aspiration to orchestrate particular urban processes and ways of life through computational logics of programming. The standards that regulate smart cities developments are transcoded into software instruments that then alter the environment and consequently shape the everyday living of urban citizens.

In this context, emerging projects that seek to reconfigure educational institutions, spaces and practices within the computational urbanism of the smart city are becoming key sites for the development of the future city itself. The 'smart school' developments from across commercial, governmental and civil society sectors analysed below are both prototypical of how big data might be used to govern urban life (by tracking and monitoring populations and then programming environments to reshape their behaviours) and of pedagogical techniques that might be mobilized in the shaping of 'smart citizen' subjectivities. Educating the smart city is a process both of programming educational spaces to reshape behaviours and of enabling citizens to become skilled computational actors who can assist in programming and coding the technologies that will facilitate the flow, analysis and visualization of urban data. In this sense, the attainment of the measurable, comparable and internationally standardized smart city depends at least in part on calibrating educational spaces and practices to its sociotechnical circuitry.

Researching smart schools

Methodologically, the article is based on a mapping of the connections between social, discursive and technical elements that are beginning to constitute a 'sociotechnical imaginary' of 'smart schools'. Rather than a realist mode of inquiry, it interrogates the ways that schools are being problematized according to particular lines of thought and the kinds of futures imagined for them through particular forms of technical expertise. It provides an original analysis of the primarily promotional material produced by commercial, governmental and civil society organizations concerned with reimagining education in the context of smart cities. Jasanoff (2015) defines 'sociotechnical imaginaries' as collectively held, institutionally stabilized and publicly performed visions of desirable futures, that are animated by shared understandings of forms of social life and social order and made attainable through the design of technological projects. As sociotechnical imaginaries, smart schools are an entity of smart cities and in an important sense are not 'actually-existing' spaces (Shelton et al., 2014) but technological projects or prototypes being ushered into existence through discursive and material means.

In spatialized terms, smart schools are one example of what Rose (1999) has termed 'fabricated spaces' that are delineated and made intelligible by being ascribed particular characteristics through discursive and material mechanisms, each produced and promoted within specific social contexts. Fabricated spaces in this sense act as models or diagrams to which certain actors hope to make reality conform, serving as 'distillations of practices' for the shaping of behaviours and 'technologies for visualizing and governing urban life' (Huxley, 2007: 194). How cities are imagined or fabricated acts as a kind of modelling of ways in which human conduct might be managed towards particular objectives. Thus, Osborne and Rose (1999: 737) consider 'the city as a way of diagramming human existence, human conduct, human subjectivity, human life itself', as a kind of 'laboratory of conduct' aimed at imposing particular regularities on human action. Urban standards such as ISO 37120:2014 act as laboratory standards and programs for realizing smart cities through software enacted in urban domains, including education.

In the article, I trace the interacting technical, social and discursive elements of those spaces being imagined or fabricated as smart schools in a selection of promotional materials produced by smart cities developers and advocates, and the forms of educational conduct, action and behaviour they project. As imaginary spaces, smart schools are being fabricated through the technical interaction of devices, information, data, algorithms and code; the social interaction of actors, groups and organizations (such as software and hardware producers, governmental agencies, commercial companies and civil society organizations) and the coding and data practices they enact; and the discursive interaction of texts, documents and visual materials. The emerging fabricated space of the smart school acts as an imaginary model for the future organization of education as a socio-spatial institution – a computational urbanists' laboratory for experimenting on learners' actions, experiences and behaviours as citizens-in-the-making for the future of cities. Education is already increasingly treated as a 'computational' project, characterized by 'algorithmically driven ''systems thinking'' – where complex (and unsolvable) social problems associated with education can be seen as complex (but solvable) statistical problems' (Selwyn, 2015: 72). Sociotechnical imaginaries of smart schools amplify this system of computational thinking and the forms of technical expertise from which it emanates, by treating education as a social institution that can be optimized through enacting particular data practices. It is through such practices of computational urbanism that the task of educating the smart city can be performed.

Concepts of governmentality underpin the argument. Specifically, governmentality refers to the interlocking rationalities, institutions, procedures, techniques and practices through which particular systems of thinking about how to govern a society are articulated (Foucault, 2007). As Miller and Rose (2008) have documented, distinctive practices of governing are historically, discursively and materially constituted. The governing of contemporary 'advanced liberal societies' is one that relies on complex procedures of collecting, counting and classifying data about individuals in order to regulate and manage society as a whole. It is based on a rationality of constant surveillance, of 'seeing' and 'knowing' the activities of each individual member of the population in order to govern them appropriately, and on the belief that individuals and their behaviour and conduct are best governed through inculcating capacities for self-management and self-fulfilment. As Rose (1999: 4) articulates it, 'to govern is to act upon action'. Thus, Vanolo (2014: 885) argues that 'governmentality involves the way in which subjects perceive themselves and form their identities through processes of government which control, incite or suppress actions'. Developing this perspective in the context of smart cities, Vanolo (2014: 894) describes a form of 'smartmentality' that involves the 'production and circulation of knowledge, rationalities, subjectivities and moralities suited to the management of the smart city'. Added to this, Gabrys (2014: 35) argues, the alteration of the socio-spatial environment may itself be used as a technique to 'influence or govern individual behaviour or the norms of populations' – what she terms 'environmentality'. A powerful new form of smart and environmental governmentality is in evidence in smart cities whereby practices of governing spaces, people and objects are increasingly delegated to processes that are technologically enacted and that fundamentally alter how urban environments function.

As these accounts already indicate, a key role in governmentality is ascribed to technology. Rose (1999) refers to the idea of a 'technology' as a complex of forms of knowledge, practical techniques, textual artefacts, discursive materials, objects and devices and so on that are brought together and imbued with aspirations to shape human conduct in some way. From this perspective, digital technologies are but one kind of technology. Recast in the educational context, it becomes necessary to look at the variety of techniques installed within schooling to achieve these ends. Thus, the 'technology of schooling' in any specific context consists of particular pedagogic knowledges, civilizing aspirations, techniques of discipline and organization, standards and obligations, classrooms of a certain design, material and technical infrastructures, textbooks and other discursive products, all of them infused with the aim of shaping and inculcating particular forms of conduct (Rose, 1999: 54). Many of the software products circulating in educational aspirations for the smart city, examined below, can be viewed therefore as hybrid progeny of both computer code and of social codes of conduct which embody and materialize existing views about social ordering, control and governance. The code on which imagined smart schools will run are not just the technical 'lines of code' known to computer science, but social codes of conduct translated into the functional and operational logics of software packages. These educational spaces are to be built around the logic that the manipulation of the environment through programmable technologies and their in-built codes of conduct will enable and activate, or constrain and delimit students' actions towards particular ends. This is 'government at a distance' (Miller and Rose, 2008) whereby the programming of software by technical experts is linked to action in the classroom.

By examining the technology of schooling that is contained in sociotechnical imaginaries of education in the smart city, then, I make visible how forms of urban conduct and behaviour are to be built-in to such fabricated spaces. In the educational literature, Monahan (2005: 35) uses the term 'built pedagogy' to describe how 'spaces teach individuals proper comportment' and 'catalyze and foreclose' particular actions and experiences. Looking at this in terms of smart cities, it is therefore important to query what kinds of pedagogies are being built or programmed into the coded environment of the school in emerging imaginaries of the future city. The kinds of pedagogies to be encountered in the coded classroom are *programmable pedagogies*, scripted into being through the professional expertise of programmers. Programmable pedagogies are key techniques of the 'smartmentalization' (Vanolo, 2014) of the smart city: the lessons taught by computational systems that have been coded in accordance with the standards of computational urbanism to sculpt particular forms of conduct, catalyse particular behaviours and delimit particular educational experiences from afar. To be clear, the article examines the imaginaries of education projected in smart city developments from commercial, governmental and civil society locations, and critically interrogates how the material operationalization of these imaginaries is becoming consequential to how young people's actions might be programmed through the environment to inhabit the forms of conduct that are considered to be appropriate to participation in the smart city.

Schools as data platforms

A key feature of emerging sociotechnical imaginaries of smart schools, like the smart cities they belong to, is their dependence on massive sources of digital data. It is the potential of big data in particular that has captured the imagination of major commercial smart cities vendors such as Microsoft and IBM, whose visions of smart education systems depend on it. The Microsoft Educated Cities (2014) program provides a clear sense of how a sociotechnical imaginary of future schooling has been attached to big data developments:

> To be competitive, cities need to ensure that their citizens have access to twenty-first century productivity tools…, world-class apps and online services that make it easier to interact and collaborate. Microsoft CityNext offers students and educators solutions built on technology they're already using, including cloud, Big Data, mobile and social.

The related Microsoft CityNext (2014) white paper on education connects the four 'tech trends' of 'cloud, Big Data, mobile and social' technologies both to the smart city and to education. The IBM Smarter Education (2014) program is based on similar arguments about the real-time availability of educational data:

> Schools and universities have always recorded and stored data as they tracked grades, attendance, test scores and demographics. With the increasing availability of technology in the instructional process, educational institutions now collect, in real time, data about what their students learn and how they progress… using big data and analytics.

Like the smart city itself, the IBM Smarter Education vision reimagines school as a hybrid sociotechnical environment, where 'Today's students expect their learning environments to mirror the environments in which they grew up and now live - that is, punctuated by always-on, available-anywhere information and personalized, multichannel learning'. A smart learning space is depicted as 'being enhanced through data, mobile and cloud technology', including a mix of 'analytics, mobile, social and security solutions built on cloud infrastructure to monitor academic progress of individual students' (IBM Smarter Education, 2014).

While the collection of school data has accelerated in recent years, the processing and analysis of such abundant, varied, exhaustive and messy data has become possible only due to high-powered computational techniques that can 'automatically mine and detect patterns and build predictive models and optimize outcomes' (Kitchin, 2014a: 2). The development of new kinds of 'intelligent' and (at least partially) 'automated' data analytics has been especially significant. For example, the Microsoft Educated Cities program makes the case for using educational analytics to gain insight from a range of pedagogic, administrative and operational data:

> Educators already have plenty of administrative and economic data – the challenge is gaining insights from it… [for] better planning and decision-making as well as improved tracking and evaluation. Microsoft and our partners create education analytics solutions that help students perform better and that can be adapted to meet individual needs. The analytics tools improve administration as well with a 360-degree view of performance and operations. (Microsoft Educated Cities, 2014)

IBM's Smarter Education programme is also premised on the assumption that data analytics will be one of the key technology 'trends' driving 'the future of learning':

> Analytics translates volumes of data into insights for policy makers, administrators and educators alike so they can identify which academic practices and programs work best and where investments should be directed. By turning masses of data into useful intelligence, educational institutions can create smarter schools for now and for the future. (IBM, 2014: 5)

The report particularly emphasizes the use of 'academic analytics' to enable institutions to analyse data for insights into institutional effectiveness and 'learning analytics' to facilitate the interpretation of students' actions.

According to these programs, smart schools will mobilize data analysis as a form of artificial intelligence, making every aspect of school performance into a real-time process of data collection, analysis, feedback and even prediction, in ways that are symmetrical with the data practices of computational urbanism. Predictive tracking and sensing technologies advocated within IBM's Smarter Education program include learning analytics platforms that can track students' data over time, link them to behavioural models and then combine those data to project likely future progress, actions and outcomes. A clear example of how such data analytics capacities may be embedded in the programmable pedagogies of smart schools is provided by the IBM vision for a 'smarter classroom'. The IBM 'smarter classroom' is a 'classroom that will learn you' through 'cognitive-based learning systems' and both predictive and prescriptive analytics. Predictive tools, IBM claims, can answer the question: 'based on what's already happened, what's going to happen next?' to which prescriptive analytics then answer: 'in light of what we believe is going to happen, what is the best response?':

> These two dimensions of smarter analytics enable educational leaders to detect patterns that exist in masses of data, project potential outcomes and make intelligent decisions based on those projections. (IBM Smarter Education, 2014)

The smarter classroom exemplifies how smart schools will become able not only to provide real-time data on student activities but also to make future-tense predictions of their likely outcomes and to prescribe automated interventions that might nudge their individual and social behaviour and so pre-empt their futures. To this end, IBM has established its own high school chain in the US, P-TECH, which is intended 'to build for schools what its operations center is for cities: a single system for collecting, aggregating and analyzing data from students and teachers alike, then writing algorithms to prescribe how to cope' and mobilizing a 'software "infrastructure layer" for schools, running behind the scenes to manage students' digital textbooks and analyze their performance' (Linday, 2013). P-TECH schools ultimately act as laboratory sites for IBM to test out its analytics capacities and to realize its imaginary of Smarter Education. The IBM Smarter Education ideal of a 'classroom that will learn you' resonates with the notion that the smart city is an ambient intelligent environment that can 'think of us' as Crang and Graham (2007) have memorably phrased it.

Here we see a recursive learning process occurring between human learners, understood in terms of measurable cognition, and predictive machine learning processes. But such processes are far from accurate and impartial to human decision making and judgment. Processes such as machine learning rely on adaptive algorithms and statistical models that can be 'fed training data'; these are, crudely speaking, 'taught algorithms' that can learn from being taught with example data, but that sometimes fail to perform as expected 'in the wild' (Gillespie, 2014). As Mackenzie (2015a: 436) notes, the 'production of prediction' depends on processes of 'useful approximation' using a range of mathematical, statistical, logistic and calculative practices that are rooted in particular predictive styles and machine learning settings and situated in the province of technical experts such as engineers, mathematicians and statisticians working in university and industry settings. Moreover, predictive machine learning algorithms have to be constantly re-trained in an iterative process of monitoring, adjusting, revising and optimizing as the accuracy and generalizability of the predictive models they generate are themselves checked and analysed (Mackenzie, 2015a). IBM's classroom that can learn is, therefore, one that itself needs constant training, or educating, and one that is regulated from afar by technical experts seeking to optimize the generalizability and accuracy of their systems.

IBM's classroom that will learn you is also based on developments from within the wider IBM R&D network in cognitive computing and 'cognitive-based learning systems'. IBM's cognitive based learning technologies are built on the idea that the architectures and functions of the brain can now (at least in part) be modelled computationally. As a consequence, it is possible to create technologies that function more like human brains than programmed software; technologies that can then be embedded into schools as a cerebral augmentation to the cognitive capacities of the learner. IBM has mobilized such developments in a new research group called 'Cognitive Computing for Education Transformation', which has begun to produce prototype applications including automated 'cognitive learning content', 'cognitive tutors', 'cognitive assistants for learning' and 'personalized adaptive learning systems'. As the 'IBM Global Manager of Education Solutions for Smarter Cities' phrases it, the 'cognitive tutor' application is intended 'to supplement face-to-face teaching and ultimately replace it entirely for subjects and areas where a cognitive agent will, quite simply, do a better job of understanding the learner's needs and provide constant, patient, endless support and tuition personalized for the user' (Eassom, 2015). Clearly for IBM's technical experts such neurocomputational devices as cognitive tutors can be envisaged as automated real-time pedagogues in the enactment of education according to smart city standards.

Mackenzie (2015b) has argued that advances in cognitive computing in places like IBM are based around 'the ideal of something like pattern recognition or indeed conscious awareness' and 'abound in references to cognition, meaning, perception, sense data, hearing, speaking, seeing, remembering, deciding' and so on. Mackenzie (2015b) terms such technologies 'cognitive infrastructures' that:

> present problems of seeing, hearing, checking and comparing as no longer the province of human operators, experts, professionals or workers seeking to navigate and finesse the constraints, limitations, breakdowns and vicissitudes of infrastructures, but as challenges set for an often almost Cyclopean cognition to reorganise and optimise.

IBM's imaginary of the cognitive classroom can be conceived, then, as located in a cognitive infrastructure in which learners are to be traced through their data and where neurocomputational pedagogies such as cognitive tutoring are to be applied for the purposes of extending human cognition. The IBM smarter school is imagined as a brainy space located in the cognitive infrastructure of the increasingly sentient, smart city. Thus, learners' conduct in smart schools is to be governed at a distance through the technical expertise of programmers, data scientists and cognitive computing experts, whose understandings and theories of learning and education are encoded in, and enacted by, the data practices of increasingly autonomous cognitive machines and the programmable pedagogies they project into the apparatus of the classroom.

These examples from IBM show how smart schools are imagined as laboratory spaces where a wide variety of data practices and devices will constantly capture information about facilities, administrative processes and the behaviour, progress and movement of students. As these imaginaries are materialized through IBM's own P-TECH chain of high schools and its cognitive tutors, the student is redefined as a data object, a 'data double' (Raley, 2013) or a 'quantified self' who is known and made manageable and governable through the insights provided via quantified data. Indeed, the data-based 'quantified self' is the popular culture variant of the 'quantified student' produced by big data-based approaches to schooling in the smart city. The quantified self and the smart city are interrelated developments, with the person increasingly defined as a kind of computational system and the city understood as a kind of sentient being. While users receives information on their behaviours to assist in behavioural changes or adaptations, the information garnered from the total users of a device can then be aggregated to inform decision making, planning or predictions on behaviour and movement in smart cities where big data informs the everyday management of the environment (Evans, 2014). This is leading to the production of a 'quantified self-city' hybrid where 'the dynamics of real-time data and the prospect for behavioural change intersect in a glossy imaginary' that emphasizes both the '"fittest" bodies and "smartest" cities' (Wilson, 2015: 39). Likewise, the quantified student and the smart school are hybrid entities recursively informing one another, where the quantification of the student is used to design new pedagogic systems, from which aggregated data can then be used to measure the smartness of the school according to commonly agreed standards.

In sum, the image of the smart school as a data platform in a massive urban big data ecosystem, as depicted by IBM, resonates strongly with computational urbanist imaginings of the smart city as a real-time environment that appears more and more sentient and 'knowing' as instantaneous processes of data collection, analysis and feedback mechanisms are built-in to its operational infrastructure. Exemplifying what Ruppert (2012) terms 'database government', it is from such data practices that new computational theories of human sociality and urban behaviour are now increasingly being derived, and which are being deployed for the purposes of governing both individuals and populations. Likewise, through its data, the smart school is enabled to 'know' its quantified students intimately and to utilize that knowledge in the identification of risks and problems and the subsequent specification of remedial interventions. IBM's prototypical smarter schools for the smart city adhere to a populist logic that big data can provide real-time intelligence on pedagogic processes and even be used to support automated cognitive agents in the classroom. But it ignores critical questions about the consequences of translating students into quantifiable data objects, or about the situated practices of approximation and programming that enact such pedagogical devices.

Educating smart citizens

In contrast to the image of the quantified student as a data object acted upon by algorithmic techniques, many smart city programs strongly emphasize the idea of 'smart citizens'. The basic logic is that the economic, cultural and political functioning of smart cities will rely on smart people that can help contribute to the monitoring and management of the city itself. Gabrys (2014: 38) for example argues that the citizen is increasingly viewed as a 'computational operative' in smart cities that are understood as 'datasets to be manipulated'. One way in which smart citizens might be shaped as computational operatives of the smart city is by 'learning to code'. In recent years, initiatives designed to educate young people to learn programming skills have been proliferating, both in the UK and globally. In the UK, for example, Code Club and CoderDojo have grown rapidly as after-school programming clubs led by volunteer programmers. A nationwide campaign known as Make Things Do Stuff was launched in 2013 to promote many forms of 'digital making', including programming, personal manufacturing and designing apps. It was followed in 2014 by Year of Code, a government-backed campaign to get children to learn to code, and in 2015 by the BBC's Make It Digital campaign.

The civil society organization Nesta (National Endowment for Science, Technology and Arts) has become a particularly significant actor in mediating between the coding/making movement and the smart cities agenda. Mulgan (2014), the chief executive of Nesta, claims that it is 'promoting digital making of all kinds in cities', particularly through its educational programs. Nesta itself launched Make Things Do Stuff, has actively funded Code Club and CoderDojo, and supported the BBC Make It Digital campaign (Quinlan, 2015). In parallel, Nesta has also extensively promoted smart cities thinking and has in particular advocated citizen participation in smart cities. Its manifesto for *Rethinking Smart Cities from the Ground Up* describes how citizens might 'shape the future of their cities' through 'collaborative technologies', 'citizen sensing projects' and 'civic crowdfunding', and it promotes 'people-centred smart cities' which use 'open data and open platforms to mobilize collective knowledge', 'take human behaviour as seriously as technology' and 'invest in smart people, not just smart technology' (Saunders and Baeck, 2015). An accompanying Nesta report analysing 40 smart city governments from around the world details how the city might act as a 'digital governor' to 'foster high-quality, low friction engagement with citizens' – by enabling citizens to interact with city services and input into urban policy making through digital interfaces – and to become a 'datavore' that turns big data into 'smart data' to 'optimize city services' by allowing citizens and businesses alike to access and build services from it (Gibson and Robinson, 2015).

In this context, Nesta's learning to code and related digital making programmes have been aligned with emerging 'civic technology' and 'coding for civic service' initiatives, in which knowing how to code and make digital artefacts becomes a prerequisite for participation in the digital dynamics of new urban infrastructures (Bell, 2014). The capacity of the smart city to become a 'digital governor' and a 'datavore' is, in Nesta's imaginary, dependent upon educating citizens to become digital producers and smart people; a task that is therefore delegated to programming clubs for young people and continued through civic coding projects where those individuals who have learned to code can contribute to the production of new digital interfaces to city services. This is a process of making smart city citizens governable as active subjects of the 'datavorous' urban 'digital governor'.

Along similar lines, in *Smart Cities: Big Data, Civic Hackers and the Quest for a New Utopia*, Townsend (2013: 243) emphasizes the role of 'civic hackers' and 'civic laboratories' in the creation of citizen-centred urban services, where 'knowing how to code will be an important skill for civic improvement'. A related US initiative called MakerCities encourages people to 'hack the future of your city', transforming commercialized smart cities into maker cities crafted by 'civic coders':

> Makers are starting to reimagine the systems that surround them. They are bringing the 'maker mindset' to the complex urban challenges of health, education, food, and even citizenship. Makers will make the future of their cities. (Institute for the Future, 2014)

Based on an iterative, user-centred and data-driven approach to government, Nesta has also established a program that places '"code fellows" (data technologists and designers) in city halls to create new citizen-led digital services, often built on open data', and to share 'digital services so cities can connect with their citizens in cost-effective and engaging ways' (Nesta, 2014). These 'code for *x*' initiatives, as Nesta describes them (Bell, 2014), assume that many problems of urban government can be solved through the application of computational forms of expertise. The 'civic coder' with a 'maker mindset' perceives technology as a non-political means of intervening in urban issues, applying technical solutions to problematic effects whilst eliding the underlying social causes of such problems. 'Maker cities' as a consequence demand the technical expertise of programming and computational thinking that learning to code initiatives is designed to teach and interpolate citizens into seemingly depoliticized modes of technocratic solutionism.

An example of how learning to code, civic coding and smart cities are conjoined in emerging sociotechnical imaginaries of education is provided by the Future Makers program, part of Glasgow's Future City initiative in the UK (a £24 million government-funded smart cities showcase project). The Glasgow Future City vision emphasizes the 'literacies' required to 'empower and educate people in using city data' and the 'knowledge and skills to participate, understand or contribute to the Future City' (Open Glasgow, 2014: 4, 9). In order to promote these smart city literacies, the Future Makers program, facilitated by the Nesta-funded CoderDojo programming club, provides an 'innovative coding education programme' to develop programming and coding skills among young people (Open Glasgow, 2014: 14). Future Makers consists of coding clubs and workshops all aimed at enabling young people to help shape and sustain the Future City. Related activities in the Glasgow Future City include 'Hacking the Future' events putting citizens, programmers, designers and government staff together in teams to focus on coding citizen-centred solutions to urban problems. Future Makers thus acts in part to ensure young people are equipped with the relevant technical expertise of coding and computational urbanism to help 'hack' or code the future of the smart city.

Similarly, the Milton Keynes smart city program, a collaboration between the local government and the Open University known as MK:Smart, includes a major educational initiative, the Urban Data School. The aims of Urban Data School are to teach young people 'data literacy' to access and analyse urban datasets; to create tools and resources to 'bring data skill education into the classroom'; and to encourage new forms of 'active citizenship' through using data 'to design and evaluate Urban Innovation Projects' and to devise 'effective solutions on the local, urban and global level' (Urban Data School, 2015). Urban Data School is led by computational urbanists with a focus on 'educating the Internet-of-Things generation' (Kortuem et al., 2013) and ambitions to support learners to acquire the awareness and skills relevant to smart cities. The MK:Smart Urban Data School, like

Glasgow's Future Makers, seeks to enlist young people into the data practices associated with forms of computational urbanism that assume city services can be optimized by enrolling citizens into the computational circuits of civic coding, and thereby to enact the data practices of the urban 'digital governor' on its behalf.

In sum, through learning to code, young people are being trained as apprentice computational urbanists. As such, learning to code, digital making, data literacy and civic coding initiatives are all part of an emerging style of 'political computational thinking' familiar to many smart city visions, which translates complex social phenomena like politics, public health and education into neatly defined problems with definite, computable solutions that can be realized with the right combinations of code, computation and data literacies (Williamson, 2015b). It requires citizens to learn to code in order to help re-program, de-bug and optimize the software-supported city and all its urban services. As Vanolo (2014: 893) argues, 'citizens are very subtly asked to participate in the construction of smart cities' and 'implicitly considered responsible for this objective. This means that the citizen is re-subjectified in the form of an active citizen', enabled to participate in the programming of apparently non-political solutions to problems of urban governance:

> In other words, citizens and local communities are invested with a moral obligation to behave in a certain way and adhere to the collective project of building smart cities; in this regard, the production of 'smart citizens' can be seen as an instrument of 'government at a distance'. (Vanolo, 2014: 893–894)

In the smart city, the 'digital governor' acts at a distance by subtly regulating the actions of citizens. As Gabrys (2014: 38) argues, in this context the actions of citizens have less to do with exercising rights, responsibilities and democratic engagement and more with operationalizing computational processes 'so that smart cities will function optimally'.

Ruppert and Isin (2015: 9) note that the emerging figure of the 'digital citizen' has become 'a problem of government: how to engage, cajole, coerce, incite, invite or broadly encourage it to inhabit forms of conduct that are already deemed to be appropriate to being a citizen'. In particular, they ask how the lives of digital citizens, as 'political subjects', are 'configured, regulated and organized by dispersed arrangements of numerous people and things such as corporations and states but also software and devices as well as people such as programmers and regulators' (Ruppert and Isin, 2015: 4). Activities such as learning to code and digital making have become everyday acts that coproduce the political subjectivity of digital citizens: individuals and social groups that can act through the digital to forge styles of participation but are simultaneously shaped and constrained by the coded software devices and institutional arrangements that make such forms of urban participation possible. Projects such as Glasgow's Future City, Nesta's civic coding and MK:Smart Urban Data School exemplify how smart citizens are to be produced through their enrolment and participation in programmable urban spaces as novice computational urbanists. Education is being reimagined in such programs as an important laboratory site for experimenting in techniques to encourage young people to inhabit the forms of conduct appropriate to active citizenship in the smart city.

Conclusion

This article has provided an original analysis of how educational settings are being reimagined as spaces of real-time data analysis and civic coding, all supported by particular standards, discourses and imaginaries associated with the 'smartmentalization' (Vanolo, 2014) of the city. It has specifically documented two interrelated ways in which education is being reconfigured within smart city imaginaries. First, smart schools are to become programmable educational spaces in which many aspects of administration, leadership, spatial organization, student management, communication and even pedagogy itself are to be governed by processes programmed in code. They are fabricated spaces in-the-making that are undergirded by a dense infrastructural mosaic of standards, coded devices, data, discourses and techniques – all products of the technical expertise of programmers, data scientists, computational urbanists and their advocates, located in expert settings such as IBM as well as in government offices and civil society organizations – that will ultimately make educational institutions and processes more programmable and in that process shape the capacities and conduct of the people who move through them. Reconceived as data platforms, such schools are being positioned as responsible for educating the smart city by acting upon the competencies, conduct and even the cognition of its future citizens. While the investment in large database systems in education is fraught with concerns over privacy, ethics and the generalizability of big data (Selwyn, 2015), these are largely elided in smart city projects such as IBM's Smarter Education program which are oriented towards realizing common urban standards, indicators and measures.

Second, new programs focusing on learning to code, data literacy and civic coding – such as those enacted by Nesta, Glasgow Future Makers and MK:Smart Urban Data School – are positioning young people as apprentice data experts and computational urbanists.

By equipping young people with the relevant data literacies and coding skills, these smart city initiatives seek to encourage them to occupy the forms of conduct that are appropriate for participation in coded urban infrastructures, thus responsibilizing them as data analysts, digital makers and civic coders who will design the technologies that will enable the city, as a digital governor, to interact with its citizens and to learn about their activities and behaviours in real-time. It is in this sense that the process of educating the smart city has a double meaning: on the one hand, it involves educating people to become smart citizens who can contribute to the design of digital urban infrastructures and devices, and on the other, it also involves the use of such devices and infrastructures to enable the city itself to learn about all those individuals that inhabit it, and, as an increasingly sentient learning environment, to reshape itself around their forms of behaviour and action.

I have advanced the notion of programmable pedagogies as one way of conceptualizing how education is being reconfigured for the smart city. This concept captures how certain forms of comportment and conduct can be coded into the pedagogic structure of educational spaces through the design of technologies that, hardwired into the programmable environment, have the potential to subtly reshape behaviours according to the visions of urban social order that their designers and sponsors believe are both desirable and attainable. These pedagogies emerge from and also reinforce standards such as ISO 37120:2014 through software instruments that make classroom processes, like urban processes, into measurable and comparable indicators. Programmable pedagogies are being prototyped in the classroom through the introduction of learning analytics and cognitive computing tutors. In addition, as young people in particular are encouraged to learn to code and become sufficiently data literate to create new digital interfaces to the city, they are becoming responsible for constructing new programmable pedagogies on behalf of the urban digital governor and in accordance with the global standards that regulate smart cities development itself. By making new civic apps and interfaces with city services, they become laboratory technicians of the smart city, enabling it to function optimally. In so doing, the digital government of the smart city enacts pedagogies of normalization and subjectification that assume data-literate forms of smart citizenship are taken as the default mode of active participation. The programmable pedagogies of smart schools extend beyond the classroom into the everyday public pedagogies of urban life, where digitally enacted big data systems constantly regulate and govern people's conduct according to the standards and social codes of conduct that are written into the lines of code that constitute them. Citizens themselves are to play a part in the design of such systems as apprentice computational urbanists and in scripting the programmable pedagogies that will realize new forms of active computational conduct in smart cities.

To be clear, the projects and programs detailed in the analysis – IBM's Smarter Education, Nesta's civic coding, Glasgow Future Makers and MK:Smart Urban Data School – form an emerging assemblage of technologies and discourses that constitute a sociotechnical imaginary for schooling in the smart city. As Jasanoff (2015) details, sociotechnical imaginaries are significant because they act as publicly performed visions of desirable futures that are animated by shared understandings of forms of social life and social order and that, crucially, are made attainable through the design of technological projects. The smart cities standard ISO 37120:2014 in this sense acts as a dominant imaginary for smart cities projects, to which education is increasingly aligned. Although many of the elements that would constitute an ideal-type smart school are not, as yet, assembled into actually existing spaces, many of the coded devices, data practices, technical experts and discourses that make up this assemblage are already converging in projects that make such a future seem increasingly attainable to its advocates and sponsors. Diverse organizations from across the sectoral spectrum, such as IBM, Nesta, Glasgow Future City and MK:Smart, are all contributing to this smart schools assemblage through the forms of technical expertise they promote and the supporting discourses they circulate. Digital data analytics, cognitive computing and the learning to code movement have all been enlisted into the sociotechnical imaginary of the smart school, thus constituting an emerging technology of schooling that is infused with the aim to govern young people's conduct and capacities for action in the smart city.

Through such a technology of schooling, students are increasingly being positioned as data objects whose learning lives are to be tracked and monitored through their data points for the purposes of enacting behavioural modification techniques. At the same time, they are being solicited as active subjects who should learn to code and learn to analyse data in order to calculate and compute the future of the city itself. Just as 'the laboratory of the city' (Osborne and Rose, 1999: 741) has become a key site in the governing of human conduct, the emerging technology of the smart school is being assembled as a laboratory for experimenting on learners' actions and experiences in order to shape their subjectivities as active citizens and computational operatives of the smart city. The smart school is a laboratory for experimental forms of digital government where the sociotechnical imaginaries and expertise of computational urbanists and civic coders are to be projected from a distance into the city, both through monitoring young people's data points and through educating them to become active and responsible citizens with appropriate skills to compute the future of the city. The task of governing the future city is partly to be achieved through computational experiments in schooling the smart city and its citizens.

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