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Coding the biodigital child: the biopolitics and pedagogic strategies of educational data science

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ABSTRACT

Educational data science is an emerging transdisciplinary field formed from an amalgamation of data science and elements of biological, psychological and neuroscientific knowledge about learning, or learning science. This article conceptualises educational data science as a biopolitical strategy focused on the evaluation and management of the corporeal, emotional and embrained lives of children. Such strategies are enacted through the development of new kinds of digitally-mediated ‘biopedagogies’ of body optimisation, ‘psychopedagogies’ of emotional maximisation, and ‘neuropedagogies’ of brain empowerment. The data practices, scientific knowledges, digital devices and pedagogies that constitute educational data science produce new systems of knowledge about the child that are consequential to their formation as ‘biodigital’ subjects, whose assumed qualities and capacities are defined through expert practices of biosensing, emotion analytics, and neurocomputation, combined with associated scientific knowledges. The article develops the concept of transcoding to account for the processes involved in the formation of the biodigital child.

KEYWORDS

Biopolitics; digital data; educational data science; neuroscience; psychology

Digital data technologies play an increasingly prominent role in the collection, calculation and circulation of information about children, particularly in educational settings such as the school. Consequently, commercial companies, government departments, and non-governmental organisations alike are developing the capacity to conduct digital analyses of children’s educational data. This article examines how emerging digital data analyses of children and their education also depend upon biological, psychological and neurological knowledge of the living body of the child. Underpinning many analyses of children’s digital data are existing systems of knowledge that have been socially and technically produced through the expert practices of the biological sciences, the psychological sciences, and the neurosciences – those formalised sciences of the living body, the mind, and the brain. The practices and knowledges generated from these disciplinary settings are currently becoming embedded in the emerging field known as ‘educational data science’. For its advocates, educational data science is a hybrid of data scientific practices drawing from statistics, computer science, information science, and machine learning, combined with expertise in psychology and neuroscience from the existing field of the ‘learning sciences’ (Buckingham Shum et al. 2013). Educational data scientists are becoming new kinds of scientific experts of learning with increasing legitimate authority to produce systems of knowledge about children and to define them as subjects and objects of intervention.

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This article explores aspects of a genealogy of educational data science, tracing how its data practices produce new knowledge of children that is refracted through the disciplinary gaze of the biological, psychological, and neurosciences. Educational data science generates data scientific ways of knowing that are combined with biological, psychological and neuroscientific classifications. Moreover, as such understandings have developed, the insights of educational data science about children's bodies, psyches and brains are also being mobilised in the creation of new kinds of pedagogies that may be enacted using digital technologies. Advocates of educational data science take a pragmatic view of their field as helping to improve children's academic progress; the central contention in this article is that the field is producing a new 'historical truth' about the qualities and capacities of children, and generating associated pedagogic strategies of power that have the objective of guiding and governing their conduct (Hultqvist and Dahlberg 2001). Of course, as an emerging field, educational data science remains rather peripheral to mainstream education, and constitutes a number of practices amongst many others, situated in diverse contexts, that may be shaping how children are seen, known and acted upon. The analysis that follows focuses as much on what educational data science as a field wants to happen – its ambitions, aspirations and objectives – as well as on what is actually happening. The emphasis is on educational data science as an emerging system of thought constituted by a common vocabulary, shared practices, explanations, forms of argument, working assumptions, and ways of imagining the future.

The article consists of three genealogical case studies exploring how biological, psychological and neurological knowledges of children are being generated through emerging educational data science practices and then projected into new digitally enacted 'biopedagogies', 'psychopedagogies', and 'neuropedagogies'. It explores, first, how the biophysiological body of the child is translated into biophysical data through health-tracking devices worn on the body, and how knowledges of the biological child are from there converted into new biopedagogies (or body pedagogies) intended to encourage children to undertake data-driven practices of bodily optimisation. Second, it examines how the psychological and affective experiences of the child are captured by emotion-sensing devices, and how psychological knowledge of the child is then used to inform the creation of new psychopedagogies of emotional maximisation. And third, it explores how emerging understandings of the neurological functioning of the child's brain, defined according to neuroscientific insights about the 'learning brain', are leading to the production of new kinds of neurocomputational devices that can be embedded into new neuropedagogies of brain empowerment.

Centrally, the article is concerned with developing an account of the biopolitics of these emerging practices and pedagogies, analysing how educational data science constitutes a new politics relating to the measurement and pedagogic management of the corporeal, emotional and embrained lives of children. Analysing these pedagogic developments requires combining insights about the disciplinary 'data practices' that generate digital data with studies of the bio-, psy- and neurosciences. The educational development of new bio-, psycho- and neuropedagogies is situated in the context of emerging digitised environments where knowing, addressing and seeking to shape the bodily/biological, emotional/psychological, and cognitive/neurological comportment of people through technologies are becoming key techniques of governing. While such practices are only at this stage emerging through educational data science, the field is growing in recognition through funding, academic development and commercial support, and has the potential to become a significant biopolitical influence in the management of children. The next section provides a conceptual anchoring in recent relevant discussions and theorizations about biopolitics and new technologies, and is then followed by a brief introduction to educational data science as a new field, before moving on to the three genealogical case studies of the specific biophysical, psychological and neurological interventions being made through educational data science practices.

Biopolitics and big data

It was Michel Foucault who brought the term biopolitics into circulation. For Foucault biopolitics signified 'the entry of phenomena particular to the life of the human species into the order of knowledge and power, into the sphere of political techniques' (Foucault 1990, 141, 142). He traced how techniques designed to calculate and control the biological features of human life have come into existence through disciplines such as statistics, demography, epidemiology, psychology and biology (Foucault 2008):

These disciplines make it possible to analyse processes of life on the level of populations and to 'govern' individuals and collectives by practices of correction, exclusion, normalization, disciplining, therapeutics, and optimization. ... The discovery of a 'nature' of the population ... that might be influenced by specific incentives and measures is the precondition for directing and managing it. (Lemke 2011, 5, 6)

In the sense derived from Foucault, biopolitics signifies a particular set of strategies of power that are rooted in distinct disciplinary practices, authoritative forms of knowledge, and the historical truths they propose, which might then be translated into specific practices for intervening in and governing human lives (Rabinow and Rose 2006). As Foucault (1990, 142, 143) noted, with the emergence of techniques of corporeal control associated with biology, 'biological existence was reflected in political existence', and new strategies of 'bio-power' brought human life into 'the realm of explicit calculation', though biopolitics is by no means any longer situated only in the domain of biology.

Foucault's initial writings on biopower and biopolitics have become influential in discussions on diverse scientific and technological innovations associated with life processes. It is in the domain of scientific and technical innovations that the following analysis of educational data science needs to be situated. Particularly with the emergence of sophisticated biotechnologies, the term biopolitics has been associated with various 'human enhancement technologies' that 'are intended to act on (and in) human bodies and are bound up with ideas such as the nature of those bodies', their 'normality and desirability', and their amenability to 'controlled manipulation through technology' (Morrison 2015, 6, 12). Advanced biotechnologies have the potential to change the appearance and functioning of the body, but also to make it more malleable, correctable and improvable by turning 'individual and collective lives into information and knowledge' in order to 'intervene on them' (Rose 2007, 53). As such, the specific biopolitics associated with biotechnical innovation focuses the expert identification, classification, and administration of individuals, who are understood to be amenable to bodily, psychological and neurological optimisation. Biotechnologies for the modification of living beings mean the body is increasingly viewed as 'molecular software that can be read and rewritten' (Lemke 2011, 93). Through the intersection of biological and computer codes in biotechnology, the human body is configured in terms of sequences, cells and molecules, and in terms of software, databases and programmes that can be patched, de-bugged and optimised to produce novel configurations of 'biodigital life' (Mackenzie and McNally 2013, 74).

In one study of the genetic and computer codes that co-constitute the body, Thacker (2004, 13) has articulated how 'biological and medical approaches to understanding the body [have] become increasingly indissociable from the engineering and design approaches inherent in computer science, software design ... and computer engineering'. The body is therefore simultaneously a biological body, but also a body compiled through data extraction, analysis, modelling and visualisation, thus establishing new technical configurations which enable the biological body to surpass itself. He terms this 'biomedia'. Thacker (2004) suggests the concepts of 'encoding', 'transcoding', 'decoding' and 'recoding' to make sense of the coded corporeality of biomedia. In technical terms, *encoding* refers to the process of translating data from one format to another; in biomedia, data is seen to be amenable for extraction from bodily matter and having been encoded, to being *transcoded* across different media and formats. Thus the body can be encoded as data and then transcoded as quantifiable data across different database systems and software programmes. The process of *recoding* then refers to how such data might be programmed or re-programmed as it is distributed into different systems, in ways that mean the original data is transformed. *Decoding*

then refers to how re-programmed data can be reinserted into the body in the shape of novel products, to produce 'a rematerialized, rebodied body' (Thacker 2004, 23):

The genetic code is ... also a database ... in which code comes to account for the body ... just as the body is biotechnically enabled through code practices ...; the practices of encoding, recoding and decoding are geared both to move across platforms and to always 'return' to the biological domain in a different, technically optimized form. (Thacker 2004, 26)

The notion of the biodigital body that can be transcoded across corporeal and computational platforms to make it correctable, through 'a relative control over life' (Foucault 1990, 142), is central to the analysis of the practices of educational data science provided below. It is through techniques of encoding the child in database media, and then transcoding data between the body and the machine, that a particular historical truth or knowledge of the body, psyche and brain of the child is to be generated. Those data are then amenable to processes of recoding and reprogramming, decoding and de-bugging, to produce models that might be used to inform the design of digital pedagogies which might in turn perform the function of transcoding the optimised model to the 'rebodied body' of the child. Multiple acts of transcoding are occurring in this dynamic: the transcoding of physiological, emotional and neural signals from the body into indicators quantified in databases; transcoding of biological, psychological and neurological knowledges of the learner into the models contained in data-processing software; the transcoding of children's data across different devices and platforms; and the transcoding of corrective responses back to the body of the child via digital pedagogies.

In this context, it is important to consider how strategies of biopolitics manifest in relation to the proliferation of systems of 'datafication', whereby automated data extraction performed on the masses of user data generated through digital media platforms is assumed to reveal patterns of information about specific human behaviours (Van Dijck 2014). With the availability of big data to commercial companies and government agencies, a new form of 'soft biopolitics' is emerging, one that functions through algorithmic sorting of users' data and is 'embedded and integrated within a social system whose logic, rules, and explicit functioning work to determine the new conditions of possibilities of users' lives' (Cheney-Lippold 2011, 167). In other words, the datafication of everyday life enables powerful social actors to conduct a constant algorithmic diagnostics of patterns of human life, and to use the insights gained from those data to derive new models, classifications and theories of both individual and social behaviours (Ruppert 2012). This leads to the design of particular technologies to maximise such behaviours, shaping individuals with the correct behavioural comportment for a desired social order.

In this sense, the 'lines of code' that constitute computational technologies are also transcodings of 'codes of conduct', particular ways of conducting one's life that users are encouraged to inhabit, internalise and embody in the ways they comport themselves. Educational data science is an emerging site of scientific expertise where codes of conduct are to be transcoded into the lines of code that enact pedagogic software systems. As such, educational data science represents a significant contemporary instantiation within the pedagogic complex of schooling of longer biopolitical strategies that have sought to codify, calculate, and ultimately optimise the body, mind and brain of the child through diverse psychological and medical fields (see Rose 1996, 1999; Popkewitz 2012). The next section provides contextual details on this new field in order to stage the subsequent case studies of its interventions in the biological, psychological and neurological lives of children.

Education data science

Educational data science is an emerging, transdisciplinary field, building on both data scientific practices and existing knowledges from the learning sciences (itself a combination of psychological, cognitive and neurological sciences). As a set of practices, educational data science is being developed in academic settings, as well as through commercial organisations like Pearson and IBM. Piety, Hickey, and Bishop (2014, 4, 5) describe the field as a 'sociotechnical movement' originating in the period 2004–2007 as techniques of educational data mining were first developed. It grew from 2009 onwards as educational data scientists formed a professional community with its own conferences, associations, methods and shared styles of thinking, and especially as policymakers and funders began to see it as 'the community

dealing with 'Big Data' in education' (Piety, Hickey, and Bishop 2014, 3). Three big name advocates of educational data science, Piety, Behrens, and Pea (2013), have traced its origins to computer science techniques of computational statistics, data mining, machine learning, natural language processing and human-computer interaction.

Subsequently, Pea (2014, 37) has ambitiously proposed a new 'specialised' field combining the sciences of digital data and learning, and the construction of a 'big data infrastructure' for analysing large volumes of learning data. Specifically, he identifies 'several competencies for education data science', including computational and statistical methods, as well as cognitive science, sociocultural principles in the sciences of learning, plus psychometrics and educational measurement, cognitive neuroscience, and bioinformatics (Pea 2014, 48). Likewise, DiCerbo and Behrens (2014) of the commercial educational publisher and software vendor Pearson, also argue 'we need further research that brings together learning science and data science to create the new knowledge, processes, and systems this vision requires'. The authors argue that combining learning science with data science methods will enable educational data scientists to detect 'new patterns that may provide evidence about learning'; construct data-based profiles and 'better models of learners' knowledge, skills and attributes;' and 'to more clearly understand the micro-patterns of teaching and learning by individuals and groups'. Pearson has become a major global actor in the promotion of educational data science methods (Williamson 2016).

These competencies and practices for education data scientists provide some sense of the genealogical juxtapositions of methodologies and knowledges in the field. In addition to its social, professional and commercial formation, though, my focus is on how its practices and pedagogic technologies work to assemble children as biodigital beings. Pea (2014, 24) specifically highlights 'a pre-eminent objective' in educational data science of:

creating a model of the learner. What characteristics are important as predictors for what is appropriate to support the learner's personalized progress? What are the classes of variables and data sources for building a learner model of the knowledge, difficulties, and misconceptions of an individual?

Here, he hints towards the construction of the biodigital child through the methods, practices and technologies of educational data science. This field depends on the generation of models of learners, assembled from their digital data, which can be coded into pedagogic software tools and have the subsequent potential to shape the bodily comportment, emotional conduct, and cognitive capacities of children. Piety, Hickey, and Bishop (2014, 9) recognise that educational data science technologies 'encode various theories of learning that manifest themselves in the data the tools provide'. The underlying theories of learning contained in the information architectures of educational data science, and the models of the learner constructed by experts in the field, are therefore consequential to ways of both theorising and acting practically upon children. It is through the combination of these forms of expertise, theories and technical architectures that the child is digitally 'reodied', whose biological, psychological and neurological conditions of possibility are shaped, constrained and enacted through the suturing of software skins, data membranes, and algorithmic musculature to their biodigital bodies. This transformation is accomplished through biopedagogies of bodily optimisation, psychopedagogies of emotional maximisation, and neuropedagogies of brain empowerment, as the three following genealogical case studies demonstrate.

Biopedagogies of bodily optimisation

One key area in which educational data science practices and technologies are emerging is in the monitoring and correction of children's biophysiological bodies. There is a long history of using data practices to measure children's physical activity, most notably with Fitnessgram in the US; more recently, there has been a growth of interest in the use of mobile, wearable health-tracking and physical activity monitoring devices in schools (Gard 2014). Indeed, the widespread acceptance of fitness and activity assessment tools like Fitnessgram suggests that newer wearable devices will be easily accommodated into the pedagogic practices of schools. Child health-tracking devices are a variant on the popular technologies of the 'quantified self' that people use to keep track of their physical exertion, calorific

intake, and more. The quantified self has become a cultural phenomenon, not just a technical fad, and the 'practices, meanings, discourses and technologies associated with self-tracking are inherently and inevitably the product of broader social, cultural and political processes', not least public health agendas (Lupton, 2016). As the hybrid product of technical innovation, cultural practice and public health agendas, these 'self-mediation interfaces with health' are now becoming 'inextricable from the manner in which people learn about health' (Rich and Miah 2014, 301). The data practices of the quantified self are also embedded in particular scientific disciplines and specialist knowledges which provide the expert descriptions and explanations of the physiological body as well as the data analytics techniques required for the devices to function as intended. Physiological codings of the body merge with computational codes in the enactment of such devices.

Although wearable health-tracking devices and apps for children remain relatively peripheral in mainstream education to date, an increasing number are now available to schools, particularly in the US. They are designed to encourage healthy lifestyles, aid dietary planning and encourage physical activity. For example, Zamzee (<https://www.zamzee.com/>), the 'game that gets kids moving', combines accelerometry technologies, game design and 'motivation science'. It consists of a wearable 'metre' device to 'measure the intensity and duration of physical activity'; an online 'motivational website' featuring challenges and lesson plans; and 'group analytics' to enable educators and school administrators to 'track individual and group progress with real-time data'. The strapline for the product is 'Motivate. Measure. Manage'.

Another health-tracking platform for children is Sqord (<https://www.sqord.com/>), 'your online world, powered by real world play', which consists of a wearable data logger, an online social media environment and a personalizable onscreen avatar. Sqord is marketed as 'one part social media, one part game platform, and one part fitness tracker'. Users can compete with one another on an online leaderboard through data produced during physical challenges, as measured by their activity trackers, and are able to win rewards for completion of goals, which can be used to purchase upgrades and personalised features. It provides a surveillant administrative reporting tool for educators to access metrics on the physical activity levels and participation of each child player. The Quantified Self Institute also manages a major research project to develop wearable activity monitors for children. Its planned device 'makes children and parents aware of their physical activity', while the analysis of the data gained from the overall users is intended to be 'used in scientific research in which awareness, behaviour and the prevention of obesity play an important role' (Quantified Self Institute 2015).

Sqord, Zamzee and others represent a convergence of devices, software, apps, techniques and discourses of self-quantification with pedagogic practices and expert physiological knowledges. They constitute an emerging form of digitally enacted 'biopedagogy', or a body pedagogy, that conveys knowledge, competencies, skills and moral codes relating to what the body is and ought to be, whose and what bodies have status and value, and what 'body work' needs to be done to make it 'fit' both in terms of health and the social order (Evans and Rich 2011). Moral codes relating to the body are inscribed into the lines of code that enact health-tracking devices. As Rich and Miah (2014, 305) have argued, 'increasingly, younger people engage with these technologies as pedagogical devices through which they learn to recognise themselves and/or others as good, healthy, active and/or having desirable bodies in the pursuit of healthiness'. Lupton (2015) terms the idealised figure of such techniques a 'socially fit biocitizen' who accepts the duty of self-responsibility and the entrepreneurial management and optimisation of one's life, including promoting and maintaining good health and physical fitness.

The hybrid mix of pedagogic technologies, moral codes of the body, and modes of self-management enacted through child self-tracking devices is ordered (at least partly) by underlying algorithms and their inbuilt models of the body. Researchers in the physiological sciences have sought to develop physiological analytics devices – based on physiological modelling practices that seek to analyse factors such as heart-rate variability, autonomous nervous functioning, and respiratory-rate variability – as a way to quantify other underlying physiological processes. Health informatics, bioinformatics and digital medicine also provide the expert knowledges on which physical activity monitors are programmed, with biological classification systems built-in to the algorithms that enact health-tracking analytics. These

knowledges are then entwined with expertise in machine learning and predictive analytics algorithms, so that the devices can approximate or predict users' future health and automate prescriptive pedagogic recommendations on exercise and diet.

Within educational health apps like Zamzee, then, techniques of physiological analytics perform a kind of digital dissection of the child's body, encoding it as a data model that can be compared against standard physiological classifications held in a database, and then produce feedback to the child in the shape of prescriptions for subsequent activity. The classifications and models of biophysiological functioning produced by expert practice are coded into the devices, and reflect specific scientific systems of thinking that are sometimes controversial and contested (Stokel-Walker 2015). Moreover, Zamzee and others act as normalising technologies that induct children into habits of self-quantification, behaviour change and self-care, not just for the purposes of better self-management but to support a governmental and economic ideology of individualised 'wellness' (Cederstrom and Spicer 2015).

In sum, biophysiological analytics devices for children represent the hybridity of insights about the body emerging from biological and physiological sciences with biosensing technologies that can detect signals from the body and transcode it into measurable data, along with new biopedagogic techniques of bodily optimisation which accord with moral codes around healthy bodies and political priorities around self-care and biocitizenship. The body is brought into the realm of both calculation and transformation (Foucault 1990) by such devices, so that the biological codes of the body and the computational codes of database media operate in a constant spiral loop of encodings, transcodings and recodings. Signals from the body become data; those data are transformed into biofeedback and transmitted back to the user, whose bodily routines and behaviours are thus shaped and constrained. Within this set of transcodings, the body of the child encounters expert scientific knowledges and biophysiological explanations and models that, along with moral codes and political preoccupations with bodily and societal health, are encoded in the data analytics and data models that enact emerging devices such as Zamzee and Sqord. These devices classify the child as normal or aberrant, and then generate pedagogic prompts that are intended to change their bodily behaviours to fit ideals about socially fit biocitizenship. The body of the child is modelled as a kind of biological software that can be debugged, patched and re-programmed through digitally enacted biopedagogies – a body-in-beta.

Psychopedagogies of emotional maximisation

Some personal analytics devices are designed to monitor emotional activity too. The analysis of children's emotional data has become a core concern in educational data science. For example, Pea (2014, 28) proposes using data scientific methods to engage with "non-cognitive factors" in learning, such as academic persistence/perseverance (aka "grit"), self-regulation, and engagement or motivation, that are 'improvable by appropriate practices'. Various techniques of measuring the 'emotional state' of learners include collecting 'proximal indicators that relate to learning' through such techniques as 'facial expressions detected by a computer webcam while learning' (ibid., 32), plus other data sources like 'video, eye tracking, and skin temperature and conductivity' (ibid., 46). Piety, Hickey, and Bishop (2014, 3) also promote data science methods to measure 'student characteristics' including:

cognitive traits like aptitudes, cognitive styles, prior learning, and the like, as well as the learners' non-cognitive characteristics such as differences in levels of academic motivation, attitudes toward content, attention and engagement styles, expectancy and incentive styles ... persistence through adversity ... [and] tenacity or grit.

The discourse in the two texts of non-cognitive student characteristics of motivation, engagement, 'grit', self-regulation, emotional state, and so on, is highly indicative of the strongly psychological genealogy of the education data science field. It particularly points toward the possibility of using digital devices to collect and calculate data about children's emotions during educational experiences, and then offer psychologically defined prescriptions towards emotional maximisation.

Initiatives drawing on the 'psy-sciences' to promote non-cognitive learning have been termed 'psychopedagogy' (Burton 2007). Many psychopedagogic initiatives are infused with objectives to

manage children's emotions, happiness and well-being, a task that is increasingly seen through the lens of educational data science as possible using digital devices. One such example is ClassDojo (<https://www.classdojo.com/>), a free mobile app that allows teachers to award 'positive' Dojo points for individual children's behaviour and participation in the classroom. Launched in 2011, by 2015 its founders reported over 3 million subscribing teachers, serving 30 million students across 180 countries worldwide. Reward points can be given under default criteria of 'hard work', 'participating', 'helping others', 'teamwork', 'leadership' and 'perseverance and grit'. Behavioural targets can be set for both individuals and groups to achieve positive goals. Teachers can produce visualisations for each child to show their progress over time, and can also instantly contact parents with photos and text messages. One of the slogans for ClassDojo is 'happier students, happier classrooms!' Its founding directors describe the purpose of ClassDojo as reducing behaviour problems and promoting 'character development' in schools (ClassTwist 2015), and it is underpinned by particular psychological concepts from character research. Its website cites character research such as the book by journalist Paul Tough, *How Children Succeed: Grit, Curiosity and the Hidden Power of Character*, and it is explicitly modelled on the US network of KIPP schools (Knowledge is Power Programme). KIPP's approach focuses on 'the development of character' and is itself explicitly grounded in the positive psychology of Martin Seligman, author of texts on 'authentic happiness' and 'flourishing'; thus, KIPP's 'character work focuses on seven highly predictive character strengths that are correlated to leading engaged, happy and successful lives: zest, grit, optimism, self-control, gratitude, social intelligence, and curiosity' (KIPP Foundation 2015).

The psychopedagogy of ClassDojo addresses and represents the child through the gaze of positive psychology and techniques of behaviour management. It enables this gaze into the classroom through a mobile digital app that itself promotes a form of positive surveillance which makes every child's character the constant object of scrutiny and visibility within the classroom and the administrative reporting infrastructure of the school and invites parents to participate in the psychological surveillance of their own children through real-time visualisations of their data. Dojo points are ultimately crafted as data indicators of children's character.

Perhaps the most significant educational data science instantiation of psychopedagogy is 'emotional learning analytics'. Learning analytics itself is one of the central technologies of the educational data science field, defined as 'the measurement, collection, analysis and reporting of data about learners and their contexts, for purposes of understanding and optimising learning and the environments in which it occurs' (LAK 2011). Emotional learning analytics extends these capacities to capture real-time data about children's affective and non-cognitive experiences during learning programmes, making extensive use of psychometrics, sentiment analysis, and natural language processing, in order to enable the automatic detection, assessment, analysis and prediction of emotions through measurable behavioural indicators. The aim of emotional learning analytics is:

to integrate automatic emotion analysis ... into learning analytics measures in order to achieve a holistic view of the learners' progress and uncover any potential risks due to negative emotions ... [and] the use of the automatic detection, assessment and analysis of emotions to provide further assistance, personalised feedback and guidance in online courses. (Montero and Suhonen 2014, 165)

Automated forms of emotional learning analytics can provide teachers with the emotional information required to decide on appropriate pedagogic intervention, enable educational data scientists to gain new insights into the affective dimensions of schooling, enable school administrators to access visualisations of pupils' affective experiences, and help children themselves to understand their emotions.

An associated range of biosensor and biometric technologies for measuring children's moods have been developed for schools, though many remain prototypical to date. Designed to detect excitement, stress, fear, engagement, boredom and relaxation through the skin, student sensor bracelets (funded by the Bill and Melinda Gates Foundation) send a small current across the skin and measure changes in electrical charges as the sympathetic nervous system responds to stimuli. These electrodermal skin response bracelets measure how well the skin conducts electricity, which varies with its moisture level; sweat glands are controlled by the nervous system so skin conductance can be used as a physiological indicator of an emotionally aroused response. Another prototype device, called EngageSense, consists of

a computer-mounted webcam connected to facial recognition software and computer vision algorithms that have been designed to measure and monitor children's levels of emotional engagement through eye-tracking and facial expression. EngageSense is intended to provide teachers with an automated metric of student engagement throughout the day, which can then be used to tailor subsequent pedagogic routines to heighten positive emotional responses, such as motivation, attention, and engagement, and minimise negative emotions, such as confusion, distraction or anxiety. Biosensor and face reading technologies record biophysical signals from the body of the child as indicators of these underlying emotional processes, as defined by psychological forms of emotion classification and modelling. Psychobiological insights into eye movement twinned with technical expertise in eye tracking, the science of facial expression twinned with computer vision algorithms, and the coupling of biometric techniques of electrodermal monitoring with the psychology of engagement and motivation science, represent the hybridity of psy-science with educational data science in the enactment of the devices.

Significantly, emotional learning analytics and related applications depend on expert techniques that can classify human emotion. Rientes and Rivers (2014) have reviewed over 100 different measurable emotions, each linked to different methods of identification, classification and measurement. As Montero and Suhonen (2014) note, research on the emotions in education is rooted in different branches of the psy-sciences which have translated positive emotional concepts such as joy, satisfaction, motivation, pride and happiness, as well as negative emotional concepts such as frustration, boredom, confusion, stress, and anxiety into measurable classification systems. The identification and measurement of psychological indicators through content analysis, natural language processing, emotion questionnaires, as well as big data techniques of sentiment analysis and 'machine emotional intelligence' systems are all expert techniques for mining children's emotions, and 'with increased affordances to continuously measure facial and voice expressions with tablets and smartphones, it might become feasible to monitor learners' emotions on a real-time basis' (Rientes and Rivers 2015, 15).

Emotional learning analytics and positive behaviour apps, as a particular psychopedagogic branch of educational data science, are an instantiation of a broader set of historical, social and technical developments relating to the measurement of the emotions. The psy-sciences have long played a significant role in generating classifications by which children are measured and monitored. Through psychological techniques, children have been made visible and assessable through scales, charts, visual displays and other inscriptions pertaining to norms of posture and movement, personal habits, personality, and diverse forms of conduct. These transform the child through the 'scientific and technical imagination' into an 'object-child', rendered in 'manipulable, coded, materialised, mathematized, two-dimensional traces, which may be utilised in any procedure of calculation' (Rose 1996, 112).

In the contemporary big data setting, techniques of emotion measurement and management have been developed further in commercial and governmental objectives. Davies (2015) has detailed how the psy-sciences have proliferated through big data, face-reading software, sentiment analysis and 'more emotionally intelligent computers' that can be taught how to interpret human emotional behaviours and produce social trend data on population mood. These technologies enable unprecedented psychological tracking and gauging of the emotions of both individuals and populations, but can also be programmed to judge and influence feelings. As a consequence, 'the truth of our emotions will, allegedly, become plain, once researchers have decoded our brains, faces and unintentional sentiments', and 'society becomes designed and governed as a vast laboratory, which we inhabit almost constantly in our day-to-day lives' (Davies 2015). The scientific roots of such practices lie in economic variants of psychology, such as behavioural science and happiness economics. These psy-sciences have ascertained that humans are susceptible to unconscious emotions and sentiments, and can therefore be 'nudged' to change their behaviours and decision-making towards healthier lifestyles and more emotional fulfilment (Jones, Pykett, and Whitehead 2013). Such techniques have now been installed in the dominant operating model of many governments. The sciences of 'nudge', happiness and well-being indicators, and the mobilisation of techniques of sentiment analysis, represent the mass psychological surveillance of population mood being carried out by scientific experts on behalf of governments. Through such techniques, psychopedagogies of emotional management extend beyond the school walls into the

governance of the social order as a whole. Individuals and populations alike are increasingly amenable to a constant psychological and emotional analytics, producing an affective audit trail that can be mined for purposes of governmental prediction and pre-emption. They are exhorted to turn their lives 'into an exercise in wellness optimisation' as part of a new 'biomorality' that demands individuals act to become more happy and healthy even as governmental austerity cuts into welfare and social services provision (Cederstrom and Spicer 2015, 3).

In sum, through wearable emotion sensors, emotion analytics and positive behaviour apps, it is becoming possible for educational data science to conduct a constant diagnostics of children's feelings while undertaking learning activities. These technologies diagrammatize the emotional child as a cognizable and calculable object, amenable to surveillance by the teacher, school administrator, and the parent. They are based on psychological research on psychobiological indicators of non-cognitive and emotional learning, but also sustain a longer line of psychological thinking which, for the past century, has sought to surveil, codify, calculate, predict and maximise the emotional functioning of the child through normative classifications (Popkewitz 2012). With the rise of sentiment analysis techniques and face-reading software, alongside the proliferation of positive psychology, the emotions of the child can be read off digital devices in real-time to inform pedagogic interventions which are intended to change their behaviours. These devices ultimately educate children to inhabit a wider milieu in which constant psychological surveillance is undertaken for the purpose of monitoring and ordering the mood of the population as a whole. The affective algorithms of emotional learning analytics work on new expert models and classifications of human emotion, and constitute a new mode of measurement and pedagogic intervention in the psyche of the child by encoding the feelings of the child into software systems that are designed to recode those feelings. A biopolitical strategy of the calculation and transformation of the emotional life of the child is proposed and enacted by such devices and their producers, one aimed at producing emotionally maximised individuals whose personal well-being can be calculated into social trend data on societal well-being.

Neuropedagogies of brain empowerment

While psychology has long turned children into objects of surveillance and intervention, in the last 10 years the insights of neuroscience have increasingly been applied in education. Terms such as 'neuro-education' and 'neuropedagogy' reflect a controversial 'dispersal of neurobiological language, imagery, symbolism and rhetoric within formal and informal learning environments' (Busso and Pollack 2015, 169). These terms articulate the mobilisation of neuroscientific knowledge of the learning process for the design and application of better neuropedagogies which 'can help you to achieve an almost entirely interiorised self-mastery, enhancement, betterment', or 'self-optimization' (Pykett 2015, 23; also De Vos 2016).

The proliferation of neuroscience in education is also related to a much broader 'biopolitics of the brain', an extension of neurobiological explanations that influence how human beings are conceived, addressed and managed:

[I]t is the experts of the brain, rather than of 'psy' or society, who will enable us to address the 'grand challenges' facing our societies in the future. ... [T]he problems of governing living populations ... [and] the conduct of human beings [has] come to require, presuppose and utilize a knowledge of the human brain. (Rose and Abi-Rached (2014, 3–5)

Knowing how the child's brain functions has therefore become an increasingly desirable challenge for neuroeducation researchers, whose insights may make it possible to analyse the cognitive processes and neural functions that underpin learning itself. The potential promise of such approaches is to develop an expert system of knowledge of the brain that can be used to inform the design of new methods, techniques and technologies which might enhance, optimise and empower children's cognitive functioning directly through shaping the neural structure of the brain itself. As Pykett (2015, 97) notes, however, there is often a tendency in neuroeducation to treat the functional architecture of the brain in explicitly determinist terms, and even 'to reduce learning to an algorithmic or computational process'.

Some brain-based technologies seem quite far-fetched. These include wearable functional magnetic resonance imaging brain scanning devices that use optical topography and neuroimaging techniques to measure and visualise changes in blood flow to different areas of the brain, and robotic systems that can adapt to the mental state of their human controllers. In education Meyers (2015) has argued that there is potential for neurosensing devices to be used by teachers to measure students' brain activity in real time:

Neurosensors ... could provide insight into students' cognitive activity using ... technology that measures brain activity Identifying which students are expending a higher amount of cognitive energy on an exercise ... teachers could send a 'haptic' vibration – similar to silent notifications on mobile devices – to a student's wearable or tablet, redirecting her attention or behaviour.

The merging of neurosensing, surveillance, and haptic 'nudges' represented by such a device is infused with clear biopolitical objectives to observe, calculate and manage children through both their biophysical bodies and their neurobiological brains.

More concretely, the development of 'cognitive-based learning systems' by the technology company IBM, as part of its Cognitive Computing for Education programme, represents a serious attempt to merge neuroscience with educational data science. Cognitive learning systems are an emerging development of the field of cognitive computing and machine learning algorithmic techniques. Whereas conventional machine learning algorithms depend on being trained with example data (sometimes termed 'supervised learning'), and then constantly re-trained as the accuracy and generalizability of the predictive models they generate are checked and analysed (Mackenzie 2015), cognitive computing systems are designed with the capacity to process, and learn from, natural language, interactions with users, and other unstructured data ('unsupervised learning') in ways that emulate the neural networks of the human brain.

Underpinning such systems are neuroscientific conceptualizations of the 'plasticity' of the brain. Neuroplasticity is the understanding that the brain's neural network architecture is pliable, flexible, and constantly adapting to environmental input. Consequently, new techniques are now being devised to recognise and manage the processes involved in shaping and reshaping the brain which, based on insights about neuroplasticity, promote the idea that the brain is flexible, mouldable, able to be trained, rewired, improved and ultimately optimised throughout one's life (Rose and Abi-Rached 2014). These new understandings of 'the social life of the brain' are increasingly animating public discourses, policies and practices in healthcare, education and other social domains (Pickersgill 2013, 322). As a consequence, the brain is now increasingly perceived within neuroscience as a social 'learning brain' that is in a lifelong state of neuromorphic adaptation to environmental stimuli. Cognitive computing represents an attempt to materialise this plasticity of the brain in silicon, and IBM's Cognitive Computing for Education programme represents a neuroscientific advance in educational data science.

IBM has become a dominant centre for research and development in both neuroplasticity and cognitive computing. Its own 'Brain Lab' has been an important site for the production and dissemination of neuroscientific knowledge of brain plasticity. Subsequently its cognitive computing systems are:

designed to learn dynamically through experiences, find correlations, create hypotheses and remember – and learn from – the outcomes, emulating the human brain's synaptic and structural plasticity (or the brain's ability to re-wire itself over time as it learns and responds to experiences and interactions with its environment). (IBM Research 2011)

Recent R&D in this area includes IBM's Watson supercomputer, and the development of 'neurosynaptic chips' (the 'brain chip') and 'scalable neuromorphic systems' that can emulate the neurons and synapses in the human brain, referred to in promotional IBM literature as 'computing brains', 'systems that can perceive, think and act' (Modha 2013).

Adapting these ideas within its Cognitive Computing for Education programme, IBM's data scientific vision of the classroom in five years proposes a 'smarter classroom' – a 'classroom that will learn you' through 'cognitive-based learning systems' (IBM Research 2013). The cognitive classroom promises personalisation of the learning experience, real-time feedback on learner performance, adaptive learning software that can learn from and adapt to the learner, and intelligent software tutors that can automate remedial intervention or even prescribe appropriate curricular content or automate pedagogic tasks.

IBM's Cognitive Computing for Education programme director has presented the cognitive classroom in terms of intelligent, autonomous systems that merge brain science with computer science:

[I]n the era of cognitive computing ... the computers have attributes that allow them to learn and interact with humans in more natural ways ... [while] advances in neuroscience, driven in part by progress in using supercomputers to model aspects of the brain ... promise to bring us closer to a deeper understanding of some cognitive processes such as learning. At the intersection of cognitive neuroscience and cognitive computing lies an extraordinary opportunity ... to refine cognitive theories of learning as well as derive new principles that should guide how learning content should be structured when using cognitive computing. (Nitta 2014)

The prototype innovations developed within IBM's Cognitive Computing for Education programme include automated 'cognitive learning content', 'cognitive tutors' and 'cognitive assistants for learning', all 'designed with a deep understanding of underlying cognitive neuroscience as well as cognitive theories of learning'. For example, 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 personalised for the user' (Eassom 2015). Such developments assume that the combination of cognitive computing and cognitive neuroscience is not just a new technical frontier of development, but an emerging scientific frontier in the generation of new knowledge and theories of learning itself.

IBM's neurocomputationally cognitive classroom that can learn like the plastic human brain has significant implications for how children are understood and acted upon pedagogically. As a result of recent discoveries around neural plasticity, Fitzgerald and Rose (2015) argue, there is emerging consensus that neurobiological mechanisms exist through which 'environments get encoded in brains' and aspects of social life are incorporated into neurobiological structures. Digital media plays an important role in this dynamic, with humans and technologies understood to 'coevolve' together 'technogenetically':

As digital media ... embedded in the environment, become more pervasive, they push us in the direction of faster communication, more intense and varied information streams, more integration of humans and intelligent machines, and more interactions of language with code. These environmental changes have significant neurological consequences. (Hayles 2013, 11)

In addition, Hayles (2014, 202) refers to 'nonconscious cognitive systems' that can employ learning processes modelled on those of embodied biological organisms, using their experiences to learn, acquire skills and interact with people. When nonconscious cognitive devices penetrate into human systems, they can then potentially change the dynamics of human behaviours and cognitive processes. Combining neuroscience conceptualizations of brain plasticity with media technologies, Hayles (2013, 123) thus refers to a 'technogenetic spiral' that 'changes brain morphology and functioning', and with it human cognitive capacities.

Through such brain-based neurocomputational techniques, neuroscientific forms of knowledge and expertise are becoming part of a concerted attempt to re-imagine the human subject in terms of the functioning of the brain, sometimes rendered reductively as a computational or algorithmic process (Pykett 2015). The neuroscientific inspiration for cognitive classrooms itself might be understood as changing the ways in which subjects are conceived, constituted, shaped and managed – as subjects with plastic brains that can be optimised and modified through their distribution into neurocomputational cognitive systems. They transform neural processes into 'forces that could be modified' and 'distributed in an optimal manner' (Foucault 1990, 142). In this sense, the cognitive classroom envisaged by IBM manifests a novel neurocomputational biopolitics in which brain functions are encoded as data, and then transcoded across cognitive learning algorithms and applications that are designed to augment human cognition by acting technogenetically on the plasticity of users' neurobiological structures. The biodigital child produced by the cognitive classroom proposed by IBM is to be distributed into neurocomputational systems of brain empowerment, with a plastic learning brain remoulded through its coevolution with adaptive, responsive and nonconsciously cognitive computing brains. These neuropedagogic environments are both modelled on the learning brain, and also intervene in the neural organisation and empowerment of the learner's brain.

Transcoding childhood

Recently, Fitzgerald and Rose (2015) have argued for close attention to the ways that the social environment 'is experienced in body, brain and mind' and 'gets under the skin'. In this article I have begun to map out how the methods, practices and technologies of educational data science are beginning to exert consequential effects on children through data-driven educational environments. As schools increasingly become sites punctuated with data technologies that can both collect data from children and provide feedback to them, they are transformed into new kinds of digitised, even cognitive environments that can get under the skin of children, with consequences for their bodily comportment, emotional experience, and cognitive functioning. Educational data science is not just a field of inquiry, but in its pedagogic enactment has the potential to become legible as traces in the corporeal, psychological and neural biology of children. In this sense, educational data science is a significant, albeit emerging and disparate, field of biopolitical intervention, one that represents 'methods of power and knowledge' which seek to 'control and modify' human 'life processes' (Foucault 1990, 142).

Its emergence as an expert field of knowledge and power is part of a wider context in which 'contemporary policy experimentation has been shaped explicitly by behavioural, psychological and neuroscientific evidence', and in which the 'cognitive, emotional, neurobiological and behavioural processes of the citizen are seen as the new target points of strategic, intelligent and effective policy strategy' (Pykett 2015, 2–4). The educational data science field is constituted by diverse forms of expertise, each of which generates its own data practices, methods, techniques and devices; these in turn are carriers of specific models of the learner which inform the design of pedagogies and are infused with objectives to inculcate particular capacities, forms of comportment and conduct. Expertise in the sciences of the physical body, the psychological sciences of the emotions, and the neurosciences of the learning brain of the child are all enrolled into this field and encoded in its technologies. In short, educational data science generates new ways of knowing, and acting upon, children by combining data scientific practices of measurement and modelling with the expert knowledges produced by biological, psychological and neuroscientific practices. The practices, models and pedagogies associated with these approaches seek to produce a child whose body is understood to be optimizable through practices of self-tracking; whose emotions are the focus for techniques of maximisation through emotion analytics; and whose brain is understood to be amenable to empowerment through its augmentation by distributed cognitive computing devices (see Table 1).

The concept of transcoding has been advanced as one way of detailing the biopolitical strategies of educational data science. The models, theories and the underlying scientific forms of expertise and knowledge that underpin such technologies as activity monitors, emotion analytics, and cognitive tutors are encoded as data, from where they may be transcoded across different media formats and software systems, and then the data may be recoded and transcoded back to the user so as to affect the functioning of the body from which the data originated. Human action, emotion, and cognition are modelled from the 'world out there' and transcoded into 'a world in here, in the algorithmic machine' (Neyland 2015, 129), where calculative and analytics techniques can be performed on them in order to produce pedagogic feedback that might influence and change human behaviours. In the emerging educational approaches detailed in this article, that feedback takes the form of specific kinds of digital biopedagogies, psychopedagogies and neuropedagogies. These contemporary biopolitical practices are 'based on an altered and expanded knowledge of the body and biological processes ... as an information network rather than a physical substrate or an anatomical machine', that makes 'the reality of life conceivable and calculable in such a way that it can be shaped and transformed' (Lemke 2011, 118, 119).

The methods, practices and technologies of educational data science ultimately constitute a range of biopolitical pedagogies that are mobilised with the purpose of governing the conduct of children. Educational data science is a significant contemporary instantiation of biopolitical strategies previously associated with psychological, medical and biotechnological interventions into human life, and is genealogically derived from such practices as well as from more recent developments around digital data. Through its data, the body, emotions and the brain of the child can be known and acted upon via

Table 1. Approaches of educational data science.

Child	Forms of expertise	Data practices, techniques & devices	Theory & model of the learner	Pedagogy	Objective
Body	Biological sciences	Wearable activity monitors & meters	Biological software	Biopedagogy	Body optimisation
	Physiological science	Biophysical sensors	'Buggy', re-programmable body		
	'Quantified self'	Physiological analytics Personal analytics	Correctable corporeality		
Psyche	Psychological sciences	Emotion learning analytics	Psychologically susceptible	Psychopedagogy	Emotional maximisation
	Positive psychology	Sentiment analysis	Emotionally irrational		
	Behavioural science	Biosensor bracelets	Socially manipulable		
	'Nudge'	Face recognition & eye tracking			
Brain	Neuroscience	Cognitive tutors	Neural plasticity	Neuropedagogy	Brain empowerment
	Cognitive neuroscience	Wearable brain-scanners	Neural networks		
	Neuroeducation	Neurosynaptic & neuromorphic systems	'Learning brain'		
	Cognitive computing				

the disciplinary expertise of biophysiological, psychological and neurological sciences. As 'methods of power', as Foucault (1990, 141) has described them, these sciences of human life have become 'capable of optimising forces, aptitudes and life in general without at the same time making them more difficult to govern'. Scientific methods of life management have become key techniques in the governing of contemporary societies, and educational data science is poised to enact such methods of power in the management of the lives of biodigital children. Though educational data science remains at present a newly emerging field with a shared system of thinking, rather disparately enacted through various researchers and commercial vendors, it appears likely to expand in scale and influence as financial support, academic credibility and commercial backing accrue to it. A new systematic scientific knowledge of the living body of the child, and a historical truth of the child as a malleable, correctable and optimizable biophysiological, psychological and neurological being is beginning to be produced through its data practices, with potentially significant consequences for how children are addressed, guided, and educated to comport themselves through their bodies, emotions and brains.

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