

# Amazon and the new global connective architectures of education governance

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[Author manuscript published in *Harvard Educational Review* (2022) 92 (2): 231–256,  
<https://doi.org/10.17763/1943-5045-92.2.231>]

## Abstract

In this analytical essay, part of *Harvard Educational Review*'s Symposium on Platform Studies and Education, Ben Williamson, Kalervo Gulson, Carlo Perrotta, and Kevin Witzenberger argue that global technology companies have begun acting as governance organizations in education. Their analysis focuses on the global technology company Amazon, which has begun penetrating education through a connective architecture of digital infrastructure and platform services. Through analysis of Amazon technical documentation and publicly available materials, the authors identify and examine five interlocking governance operations and their effects: inscribing commercial business models on the education sector; habituating educational users to Amazon technologies; creating new interfaces with educational institutions; platforming third party education providers on the cloud ; and seeking market dominance over provision and control of key information infrastructures of education. In showing how Amazon is potentially developing infrastructural dominance in the education sector as part of its transformation into a state-like corporation with significant social, technical, economic, and political power to govern and control state and public services, this article highlights broader implications of increasing technological governance in education.

## Keywords

artificial intelligence, data, governance, infrastructure, platforms

## Introduction

Digital platforms and information systems are shaping educational practices, institutional processes, and forms of teaching and learning. Since the 1990s in the US and beyond, computer systems for processing data have become integral to policy approaches focused on performance-based accountability, evaluation and comparison (Anagnostopoulos, Rutledge and Jacobsen, 2013). The increasing emphasis on educational performance data over the ensuing decades has involved the production of ever-more complex information systems, giving rise to particular schooling practices centered on standardized testing, curricular standards, teacher evaluations, reporting and improvement measures (Grek, Maroy and Verger, 2021). These developments are now evolving further with the advance of digital learning and teaching technologies, the growth of the commercial

education technology (edtech) industry, and the emergence of a vast range of “data-driven” technologies for use in educational policy and practice settings (Williamson, 2017; Mirrlees and Alvi, 2020). Such technologies include learning management and student information systems, digital learning platforms, big data and artificial intelligence (AI) applications to predict and adapt to student performance, and corporate cloud computing infrastructures for hosting digital services and performing data analysis (Wyatt-Smith, Lingard and Heck, 2021; Pangrazio and Sefton-Green, 2022). Beyond their technical forms, these developments afford novel capacities for measuring, monitoring and managing education systems, institutions, staff and students, and make new forms of digital, data-intensive education possible (Gorur, Sellar and Steiner-Khamisi, 2019; Decuypere, Grimaldi and Landri, 2021). In this context, global corporate technology operators are becoming influential actors in education, using their technical and market power to extend into schools, colleges, and policy settings, with potentially significant consequences (Lundie, Zwitter & Ghosh, 2022). The implications include increasing private sector power to define the future of education and its public values; a realignment of education to match the purported demands of the digital economy; algorithmic control of pedagogic and curricular processes; and delegation of political authority in education to automated decision-making.

In this essay we use *digital platforms* refer to internet-based software systems that connect providers, developers and users for informal sociality, information access, commerce, and the administration of essential services (van Dijck, Poell and de Waal, 2018). Common platforms include Facebook and Twitter, and in education, online learning platforms like Coursera, Schoology, and Google Classroom. Individual platforms commonly interconnect with other platforms and services through complex networked systems. *Digital infrastructures* are sociotechnical networks that include physical components like computers, cables, and data centers, computational capacities like software, networking, and data processing,, and social elements like organizations, people, procedures, and practices—all of which are connected and arranged as interoperating systems (Edwards et al, 2013; Kitchin, 2014). Increasingly, digital platforms exist in connective ecosystems held together by infrastructure technologies, which themselves rely on cloud computing (van Dijck et al, 2018). *Cloud computing* infrastructures are highly distributed technical systems for on-demand delivery of computing and data services over the internet. They provide the underlying systems of hardware, servers, storage, software, interoperability protocols, and other functionality on which other digital platforms and services can be built and hosted, and they also act as gatekeepers through which data can be managed, processed, stored and channelled (Varghese et al, 2019). Global cloud operators include Google Cloud, Microsoft Azure, and Amazon Web Services (AWS), and clouds are hugely valuable sources of income for their proprietors (Bala et al, 2021). Crucial to the connectivity and computation of platforms and infrastructures are *Application Programming Interfaces* (API). APIs integrate software applications and services, enabling the interoperable exchange of information between them; that is, APIs act as connecting points or interfaces between platforms, allowing them to interact and communicate (Snodgrass and Soon, 2019). One Ccommon API, for example, is Google Single Sign-On, which permits users to access other integrated applications without having to re-enter their identities and passwords. APIs also enable third-party platforms to interact with

cloud infrastructures like Google Cloud or AWS, facilitating access to computational functionalities such as data storage or analytics services.

Increasingly, public institutions are dependent on private digital platforms, cloud infrastructures, and APIs, with these sociotechnical systems exerting generative effects on many sectoral functions and operations (Amoore, 2020). In education, for example, the Google Classroom platform for online learning is dependent upon the Google Cloud infrastructure for computing and data functionality. It utilizes a specific API to enable a vast ecosystem of other third-party platforms to connect with Classroom, permitting seamless user access with a single Google sign-on—all of which can then exchange information through the cloud (Perrotta, Gulson, Williamson and Witzenberger, 2021). The Classroom API thus facilitates schools' access to a marketplace of platforms via the cloud, and makes possible new forms of digital, data-intensive educational practice (Decuypere et al, 2021). In this essay, our focus is on the implications of these emerging sociotechnical systems of interoperable platforms, cloud infrastructures, and APIs—what we term *connective architectures*.

The novel contribution of the essay is to pinpoint how connective architectures are changing processes of education governance. Conventionally, *governance* refers to the authoritative processes and institutions that are responsible for decision-making within formal structures of education systems. Contemporary education governance involves the use of “data-driven” decision making, based on digital information about student achievement and school and system performance (OECD, 2019). Advanced data-processing technologies and AI, which can “learn” from processing huge quantities of student and school data, are currently being promoted to support data-driven decision making and automation in education (OECD, 2021). In this context, responsibility for education governance has expanded to a range of other institutions and networks, including major multinational technology businesses that can offer infrastructure, platforms and data interoperability services (Williamson, 2017). Importantly, this means governance can occur not just in political centers like ministries of education, where authoritative decision-making takes place over whole systems, but within the schools and colleges where connective architectures function. Connective architectures can affect the ways information is generated and used for institutional decision making, but they also introduce new technical affordances into school practices, such as new platform-based learning, API-enabled integrations for increased student data collection, and advanced computing and data processing functionality from cloud infrastructures (Gulson, Sellar and Webb, 2021). The concept of governance indicates a networked form of authority, power, and control in contemporary education systems (Wilkins and Olmedo, 2019). In this context, however, official education policy mandates carried in textual prescriptions and proscriptions for practice in schools are shadowed by the instructions contained in software code, which can shape and govern educational practice from within the pedagogic and managerial structures of institutions (Williamson, 2019). We focus on the global online retail giant Amazon and its cloud computing subsidiary Amazon Web Services (AWS) as a case study exemplar of an increasingly powerful governance actor in education.

The purpose of this essay is to identify and conceptualize how Amazon has constructed a new global connective architecture of education governance, and, in a more speculative register, to consider its emerging and potential implications (Gulson, Murphie and Witzenberger, 2021). To do this, we first articulate how digital data systems have become integral to practices of governance over the last decades, paving the way for global technology corporations such as Amazon to become governing actors. We then outline our concepts and methods, building on our previous development of a methodological and conceptual approach to the study of the social, technical, economic and political interactions that constitute digital education platforms, APIs and infrastructures (Perrotta et al, 2021). Next, we outline the connective architecture of Amazon. Through its interconnected architecture of cloud infrastructure, platforms and APIs, Amazon enacts five particular operations of governance in education: (1) *Inscribing*: the ways the Amazon corporation and AWS imprint a particular business strategy on to the education sector; (2) *Habituating*: the role of AWS computing skills program in accustoming educational users to AWS technologies; (3) *Interfacing*: the gatekeeping role of AWS APIs in creating new interfaces between educational institutions and the AWS cloud infrastructure; (4) *Platforming*: how AWS enables third party platform developers to create new online educational services and shapes the edtech industry; and (5) *Re-infrastructuring*: the ways the overall connective architecture of AWS displaces the existing information infrastructures of educational institutions with the full range of AWS cloud functionality.

Through these five operations, we argue that Amazon is steadily becoming a dominant market player and a new kind of governing organization in the education sector. We follow our analysis by identifying four significant implications for stakeholders in the education sector: private “big tech” influence in public education; the repurposing of education as a producer of cloud skills for industry; algorithmic control of pedagogic processes; and the delegation of political authority over education to programmed computing systems. At a time of unprecedented political and regulatory attention to the involvement of technology corporations in the governance of societies and economies (Naughton, 2021), we offer an analytical framework and identify urgent priorities for further research on the changing social, technical, economic and political dynamics of education governance.

## Digital education and governance

In many modern states, interconnected technical systems and social practices used to collect and process digital data have become key technologies of “governance by data” (Bigo, Isin and Ruppert, 2019). Big data and AI systems from third-party private vendors are increasingly operating as “state actors” and as “algorithmic architectures” for public services (Crawford and Schultz, 2019, p.1941). Data-based forms of governance involve the gathering, storage, formatting, analysis, and transmission of digital data for purposes of measuring and evaluating, and then controlling and steering people, places and things towards specified aims, whether commercial or governmental (Isin and Ruppert, 2020). Technologies of data collection and analysis have opened up new ways of governing by utilizing vast datasets as inputs and analytical insights as outputs to identify targets of

intervention or opportunity, and thereby to control or steer states, populations and individuals (Johns, 2021). This signifies a political transformation whereby data collected and processed through interoperable digital infrastructures increasingly drive policy strategies (Fourcade and Gordon, 2020), a trend that appears to be intensifying across the globe since the Covid-19 pandemic (Taylor et al, 2020).

In this context, private technology companies and computational systems are playing key roles in core state administrative functions, as the governance authority of state agencies is outsourced to automated software systems (Calo and Citron, 2021). Fourcade and Gordon (2020, p.82) argue that government and public sector institutions often lack the material resources or technical expertise to gather or analyze data for purposes of governance, and must therefore outsource these functions to private technology organizations through a process of “cyberdelegation”. Various state and public services may be partly cyberdelegated to private technology systems, such as social welfare allocation, healthcare services, crime detection and prediction, national security, intelligence and defense, and education. The result is that digital data-processing technologies take over parts of the state’s operations, with the tasks of public governance outsourced to “state-like corporations” that then seek to reinvent traditional public functions for profit-seeking ends (p.78). One indicator of the cyberdelegation of public governance to the algorithmic architectures of state-like corporations is the extensive penetration of cloud computing in public and government services (Amoore, 2020), especially the global cloud systems of Google, Microsoft, and Amazon, which all offer extensive cloud and data services to the public sector. The expansion of cloud infrastructures to public governance is also part of the business strategy of “big tech” businesses to derive financial value from hosting external services on their cloud servers and from processing the data they generate (Birch and Cochrane, 2021).

Education governance is increasingly performed through such private algorithmic architectures too, as the historical role of statistics and metrics in education has evolved with technical developments in data processing (Piattoeva and Boden, 2020). Recent critical education policy scholarship has delineated two interconnected shifts in the governance of education, both at international scale. One is a distribution of the responsibilities and functions of state departments of education to wider webs of non-state actors, including statistical agencies, technical organizations, and private sector businesses (Ozga 2021). The reconfiguration of authority in education systems represents a shift from *centralized government* by state departments and ministries of education to more *decentralized governance* involving a range of non-state actors and new “policy networks” (Verger, Lubienski and Steiner-Khamsi, 2016). Networked forms of governance, for example, might involve businesses, philanthropies, or international organizations being directly involved in official policy production and diffusion, but equally significantly can mean non-state actors practising distinctive techniques of governance within education systems and institutions (Ball, Junemann and Santori, 2017). In terms of the techniques of governance, then, the second shift is the introduction by these new governance actors of novel technologies of measurement and data collection in schooling and higher education systems. The Organization for Economic Cooperation and Development (OECD), for example,

introduced comparative international assessments as a way to compare and improve education systems, and this has produced cascading effects in terms of increased intensity of testing and performance-based accountability in schools and more recently the promotion of big data, automation and AI in education (Grek et al, 2021). Thus education technologies (edtech) and data infrastructures have come to play key roles in how systems, schools, staff and students are measured, assessed and evaluated (Anagnostopoulos et al, 2013).

Not only are such systems used for performance measurement, but many data-intensive educational technologies used in schools combine data collection with other pedagogic and instructional functions, such as the online learning platform Google Classroom, learning management system Schoology, and the myriad integrated platforms and services with which they interact and interoperate. Claims that edtech and data systems can transform education, improve pedagogy, enhance student outcomes, and raise institutions' performance levels, are supported by international policy-influencing organizations like the OECD, World Bank and World Economic Forum, and by wealthy philanthropic and investment vehicles including the Gates Foundation and Chan Zuckerberg Initiative (Wyatt-Smith et al, 2021). Technology companies that process and use student data, then, need to be understood as enacting new techniques of governance within schools, by producing data for institutional decision-making and by reshaping educational practices around the affordances and constraints of platforms and infrastructures (Williamson, 2019). They form essential parts of the integrated digital architecture of schooling itself, often functioning interoperably to govern the daily tasks of school administration, teaching, and learning, although rarely as seamlessly as their marketing and promotion suggests (Pangrazio, Selwyn and Cumbo, 2022).

In this context, global technology providers including Amazon, Google and Microsoft have targeted education for market growth in recent years (Fiebig et al, 2021), raising urgent research questions about the role of private, proprietary systems in the governance of public and state education (Kerssens and van Dijck, 2021). Amazon, Google and Microsoft have become significant governance actors, operating through networks and relationships to influence and intervene in education, and as a result are introducing new governing technologies into educational settings in the form of hardware, software, data analytics and algorithms. In particular, Amazon and its cloud computing subsidiary AWS have penetrated education systems on a global scale and constructed a vast connective architecture of governing technologies. Amazon is paradigmatic of the "state-like corporation" that "now routinely competes with or lays claims on the state for the delivery of traditionally public services and the fulfilment of core governance functions" (Fourcade and Gordon, 2020, p.92). It has significantly advanced its AWS cloud infrastructure business to achieve "structural dominance" across a range of industries and sectors, increasingly acting as an "architecture of market power" over other industries (Kahn, 2017, p.803). Government services, the public sector, healthcare and education are the latest targets of AWS's global cloud ambitions.

## **Concepts, methods, and analysis**

Building on these insights into how platforms and infrastructures intervene in governance processes, our analysis of AWS as a state-like governance actor in education focuses on the interacting social, technical and economic factors that underpin its connective architecture and its functional operations. This translates into a theoretical and methodological strategy that combines platform and infrastructure analysis with governance analysis, necessarily drawing on conceptual and methodological approaches from within and beyond the field of educational research (Perrotta et al, 2021). Platform and infrastructure studies treat infrastructures, platforms and APIs as digital “assemblages” of various social, technical and economic components and relations (Edwards et al, 2009; Kitchin 2014; Plantin et al, 2018; Snodgrass and Soon, 2019). They focus methodologically on “disassembling” these systems to reveal their constitutive components; to surface the social, economic and technical processes involved in their production; and to trace their consequent effects (van Dijck, 2013, p.25). We complement this orientation with a governance studies focus on how governance enacted through distributed, relational networks of organizations, actors, materials, discourses and technologies (Peck and Theodore, 2015). This approach highlights how governance occurs through distributed inter-organizational and cross-sectoral networks operating beyond the boundaries of the nation state and its bureaucracies, often with global reach, and examines the specific social, economic and technical actors and relations through which governance strategies are diffused, mobilized, and implemented (Savage, 2019; Lewis, 2020).

These combined methodological approaches allow us to study AWS as an emerging social, technical and economic architecture for operationalizing new forms of education governance. We focus on AWS as the globally dominant vendor in the cloud computing market (Bala et al, 2021), as a corporation with documented aims to achieve infrastructural dominance across as many sectors as possible (Khan, 2017), and as a leading global market provider of cloud services to education in competition with Google and Microsoft (Fiebig et al, 2021). As such, AWS exemplifies how global “big tech” companies are involved in creating and promoting platforms and cloud services within education, and provides a rich empirical opening to inquire into the implications that emerge when public education is embedded in private infrastructures.

Methodologically informed by the above analytical approaches, we have engaged in extensive documentary data gathering including technical documentation and publicly available materials from AWS, especially the AWS Cloud Computing for Education pages of the AWS website, product specifications, promotional marketing, and company blog posts.<sup>1</sup> We examined and interpreted these materials using the methodological approach of disassembling platforms and infrastructures into their social, organizational, technical, and economic components, and constructed a thematic framework to show how AWS operates as a governance actor. By developing this framework and including indicative examples of effects and implications of the AWS architecture, we aim in part to catalyze future empirical research to examine how AWS produces concrete governance effects in practice. Because Amazon operates at all levels of the education system, from pre-K through K-12 to higher education, across every continent, as well as through its involvement in the edtech industry, we take a synoptic approach to understanding its role at all levels of education. We also

acknowledge that its advances into education are mirrored by its activities in other sectors, where Amazon is already the subject of considerable political and regulatory concern (Khan, 2017; Sadowski, 2020). This enables us to substantiate our central proposition that Amazon is increasingly acting as a state-like corporation and a globalized governance actor in education systems at an international scale and scope, through five distinct modes of operation.

## The connective architecture of Amazon

### 1) *Inscribing*

The business model of “big tech” companies such as Amazon, Google and Microsoft emphasizes the generation of financial value from hosting third-party organizations on their cloud infrastructures and from extracting masses of data from those arrangements (Birch and Cochrane, 2021). Specifically, Amazon’s goal is to generate value from embedding AWS into a multitude of sectors and industries (Khan, 2017), as the “increasing dependency of big tech on cloud computing for their financial success means that the companies use political, economic and technical resources to ensure that the clouds are the ‘default’ infrastructure in as many domains as possible” (Fiebig et al, 2021, p.11). The techno-economic business model of the cloud increasingly applies in education, as education technology businesses, as well as schools and colleges, become “tenants” paying “rent” for access to cloud hosting and computational services, and further value is extracted by the “landlord” from the resulting data (Komljenovic, 2021). The first part of our framework therefore identifies Amazon’s overall commercial strategy and how it inscribes that approach in its objectives for education—a process we call “*corporate imprinting*” to refer to the ways technology companies impress their business models on to the education sector (Perrotta et al, 2021).

Amazon’s role in education is underpinned by the notion of “service” rather than “product”. From its origins as an online bookstore in 1995, the story of Amazon’s growth is one of technological innovation and acquisition. AWS launched in 2006 with distributed computing and data storage services presented as a new “operating system for the internet” (Miller, 2016), and a “backbone” allowing other companies to run their business from the cloud (Gartenberg, 2021). The architecture of the AWS cloud consists of various components: an “Infrastructure-as-a-Service” through which hardware, servers, and storage are supplied; a “software stack” for platform services; data analytics applications and capacity; and a specific and highly lucrative business model based on subscriptions, multi-tenancy, and on-demand fees for usage by clients (Varghese et al, 2019). Although AWS has a less visible public profile than Amazon’s retail arm, it accounts for more than 60% of the corporation’s operating profits, making it both “a company within a company” and “the leader in public cloud computing” with more than 30% global market share ahead of competitors Microsoft and Google (Bishop, 2021).

As Amazon’s “major profit engine,” AWS has expanded beyond corporate customers to become a rentier “landlord” hosting government, state and public sector operations on the cloud (Sadowski, 2020, p.26), generating value from the “rent” paid for on-demand access to cutting-edge data processing, machine learning and artificial intelligence functionalities (Shah, 2019). It is in this

context that AWS in education needs to be situated. Education is one of sixteen key industries listed on the AWS website as “benefitting from the agility, scale and performance of the cloud.”<sup>2</sup> It reports providing services for more than 9,000 education sector customers worldwide, including schools, universities, and edtech companies.<sup>3</sup> As its major profit engine, AWS seeks to inscribe Amazon’s corporate vision of “the strategic power of data” on to public sector and educational institutions, and it has actively sought “AWS Partners” through its claim that “data are a strategic asset” to be leveraged for innovation and value generation (Carter, 2021).

The ways this process of inscribing the business model on the education takes place is evident in its commercial marketing and discourse, where AWS seeks to establish itself as an essential technical substrate of teaching, learning and administration. In AWS blog posts on education, for example, AWS promotes its capacity to improve “virtual education” (Butler, 2021), promote “on-demand learning” and “personalized learning” (van Dinter, 2021), and support “digital transformation” through “cloud-powered” services like “campus automation”, “data analytics platforms” and “artificial intelligence” (Ganadinni, 2022). These promotional inscriptions paint a seductive picture of educational improvement and transformation. Beyond being discursive, however, these forms of promised transformation require very specific kinds of contractual relations for cloud access, pay-as-you-go plans, and data agreements as per the AWS business model. AWS thus discursively inscribes and materially enacts its business model within education, impressing the techno-economic model of cloud tenancy, pay-as-you-go subscription rents, and computational outsourcing on to the education sector, and potentially affecting some of the core functions of education in its pursuit of valuable rent and data extraction. Through this strategy, AWS is fast becoming a key cloud landlord for the education sector, governing the ways schools, colleges and edtech companies can access and use cloud services and digital data, while promoting a transformational vision of education in which its business interests might thrive. The accomplishment of this operational strategy also requires the active habituation of new AWS users in education.

## 2) *Habituating*

The second architectural operation of AWS consists of its techniques for accustoming users to the functionality of the cloud and its techno-economic business model—or *habituating* users to AWS. It does so through AWS Educate, an educational skills program designed to develop teachers and students’ competencies in cloud computing and readiness for “cloud careers,” and it is intended to shape user capacities to use AWS for teaching, learning, and work.<sup>4</sup> Infrastructures like cloud computing systems include both computational components and human practices (Edwards et al, 2013). The creation of infrastructures therefore requires templates of use that allow people to coordinate their habitual practices effectively with an infrastructure (Bowker and Star, 2000). Through such templates, “apparently global systems” can “penetrate deeply into the work lives of organizations and individuals” (Edwards et al, 2009, p.370). Thus, AWS Educate seeks to establish a positive educational discourse of “the cloud,” whereby users—educators and students—are encouraged to develop their skills with AWS services and tools for future personal success. Originally initiated in the Asia-Pacific-Japan region in 2015, AWS Educate rapidly expanded to more

than 200 countries and territories, connecting hundreds of thousands of students, educators and institutions and accustoming current and future users to the AWS architecture.<sup>5</sup>

In terms of practice, the features of AWS Educate include Cloud Career Pathways and Badges, with dedicated technical courses and credentials aligned to industry job roles like cloud computing engineer and data scientist.<sup>6</sup> An AWS Educate Job Board “allows students to search for and apply to thousands of cloud jobs and internship opportunities from Amazon and other companies around the world,” and gives them “the opportunity to take the skills they’ve learned in AWS Educate’s Cloud Career Pathways directly into the workforce.”<sup>7</sup> These credentials and job board are underpinned by the Cloud Competency Framework, a global standard used to create, assess, and measure AWS Educate cloud programs informed by the latest labour market data on in-demand jobs (Flood and Hall, 2022). AWS Educate courses are based on corporate-friendly forms of computer science curricula aligned with the practical demands of working on the AWS cloud, as either a future Amazon employee or an AWS cloud tenant, with stated aims “to educate 29 million people on its cloud services platform by the end of 2025” (Gariffo, 2021). Through the AWS Skill Builder, “a learning center to build in-demand cloud skills,” AWS Educate also articulates a promotional discourse of “talent pipelines” for employment in AWS-dependent industry settings.<sup>8</sup>

Amazon’s aim is to “upskill” or “reskill” existing workers for cloud careers working with AWS infrastructure, for example by offering AWS courses for free through the Amazon.com retail site and by establishing a physical AWS Skills Center in Seattle for free learning.<sup>9</sup> The company also seeks to habituate school-age students to the technical demands and career possibilities of its cloud services. AWS supports careers and technical education in high schools through its philanthropic workforce development strategy, thereby promoting corporate curricula and teacher development programs aimed at producing the skilled labor required by the technology sector while also pairing AWS Educate with sales of its lucrative cloud services subscription contracts (Byant, 2020). In short, AWS Educate focuses on accustoming educators and learners to the AWS cloud for both short-term educational goals and longer-term labour market prospects in the digital economy (Gordon and Gurley, 2022). This strategy also serves an overarching goal of increasing user conversions and further AWS adoption and expansion. This strategy advances the general business model of “big tech” cloud firms, which seek to turn user engagement and user conversions into habitual long-term users as a route to future revenue streams (Birch, Cochrane and Ward, 2021).

Through AWS Educate and its emphasis on labour market-aligned cloud competencies, Amazon tethers personal futures to its own processes of value creation and strategies of infrastructural market dominance. These programs exemplify a shift in education policy and industry agendas towards “micro-credentials” attained through “lifelong learning” on digital platforms, rather than academic qualifications awarded by formal institutions of education (Ralston, 2021), and the development of digital learning and employment records as a means to facilitate “seamless movement between education and employment” (Cardenas-Navia and Jyotishi, 2021, n.p.). AWS promotes a normative vision of education as electronic micro-bundles of competency training and

credentials, twinned with the habituation of users to its infrastructure, all oriented towards the expansion of its global business interests. In that sense, while serving its own revenue maximization prospects, AWS Educate challenges public education values of cultivating informed citizenship with values prioritizing a privatized and platformized education dedicated to the instrumentalist development of a future cloud workforce (van Dijck et al, 2018). However, beyond habituating users through cloud career courses, the expansion of its infrastructural market power also depends on Amazon's capacity to extend AWS functionalities into third-party educational applications.

### 3) *Interfacing*

The third operation enacted by Amazon is *interfacing*. Conceptually, interfaces are points through which separate environments communicate with each other (Galloway, 2012). AWS provides new kinds of technical interfaces between educational institutions, intermediary partners, and the AWS infrastructure. This is exemplified by Amazon's Alexa, a conversational human-machine interface, or voice assistant, that sits between users and AWS (Pfeifle, 2018). Amazon launched Alexa in 2014 as its virtual assistant speaking to its users from an Amazon Echo speaker. Since its introduction, the voice assistant has migrated to other devices such as phones, smart TVs, smartboards, and automobiles. Alexa's functionality is extended through Skills, which refer to computer applications making use of proprietorial Alexa software. More than 5,000 Skills specified with the tag "Education" are available for download from the Amazon website.<sup>10</sup> Many of these Skills are custom applications allowing users to access existing educational platforms via conversational interfaces. Third parties can embed Alexa in their existing products through its Education Skills Kit.<sup>11</sup>

The Education Skills Kit illustrates how APIs act as a connective tissue between powerful global data infrastructures, the digital education platform industry, and educational institutions. Alexa's communicative interface provides an opening through which its business model can be brought into education: as educational institutions interface with Alexa through the Education Skills Kit API, they begin to develop dependencies on the AWS cloud, which promises efficiencies and enhancements that rapidly extend to administration as well as teaching and learning. For example, universities can develop their own Alexa Skills in the shape of institutionally branded voice interfaces for students to access coursework, grades and performance data; educators can embed Alexa in classes as voice-enabled quizzes and automated "study partners"; and institutions are encouraged to include Alexa Skills in "smart campus" plans.<sup>12</sup> In these ways, the Alexa Skills Kit provides a set of new AWS-enabled, automated interfaces between institutions, staff and students, mediating an increasing array of institutional relations via the AWS cloud and the automated capacities of Alexa.

The Alexa Education Skills Kit is one of many APIs that AWS provides for the educational sector to access fast, scalable, reliable, and inexpensive data storage infrastructures and cloud computing capacities, especially for computationally intensive, complex, and automated machine learning tasks. Functioning as a "gateway" technology, it allows different systems to interoperate as if they were a single integrated system and "to form more powerful and far-reaching networks" (Edwards et al, 2009, p.369). Thus, the Education Skills API enables Amazon to increase the connectivity of Alexa

and AWS to diverse and distant educational sites, to provide an interface to new educational users, and expand its market reach across the edtech industry and educational institutions alike.

Developing a Skill requires specific forms of expert knowledge. The integration of a conversational interface is mediated by AWS partners with varying degrees of direct affiliation with Amazon that can use the API to build custom applications allowing institutions to integrate with AWS services, channelling the flow of data through the official API Gateway.<sup>13</sup> The partner network includes “thousands of system integrators and tens of thousands of independent software vendors who sync their products to work on AWS.”<sup>14</sup> The AWS partner program is crucial to Amazon’s penetration into education, acting to synchronize institutions with the AWS cloud.

In these ways, the integration of automated voice assistants through the Education Skills Kit provides educational institutions a gateway into the core functionality of AWS. These interfaces depend upon the automated collection and analysis of voice data on campuses, its automated analysis in the AWS cloud, and the production of automated feedback, so generating a cascade of automation within institutions that have synchronized their operations with AWS. Alexa interfaces enabled by the API introduce institutions to the operational efficiencies offered by cloud-based automated systems, and are part of a steady accumulation of services that is establishing “automated governance” at institutional and even system-wide levels, whereby automated systems can carry out routine governance tasks (Gulson and Witzenberger, 2020). Such automated interfaces in education raise challenging issues, such as the offloading of educator judgement and feedback on to automated systems, and the outsourcing of school and college management to distant automated systems and platforms maintained by corporations (Selwyn et al, 2021). Positioned as a “study partner,” Alexa functions as an automated instructor generating quiz questions and feedback, as an automated pastoral agent providing advice and guidance to support student experience, and as an automated source of personalized information. It normalizes ideals of automation in education, including the extensive data collection and student monitoring that such automation entails. It also extends these processes of automated data collection to fresh sources such as biometric voice traces and even the use of “facial recognition algorithms” for “AI-proctored online examinations” (Gannadinni, 2022), which instantiates a “cascading logic of automation” within education whereby “sensors automate data capture, generating quantities of information that can only be handled by automated data processing and, increasingly, automated response” (Andrejevic, 2019, p.8). Private automated infrastructures like AWS and Alexa are advancing the cascading logics of automation further into everyday educational routines. AWS supports this accumulation of automation by providing infrastructure for third-party educational technology development.

#### 4) *Platforming*

Amazon has developed an explicit market strategy in education by hosting—or *platforming*—the wider global industry of education technology on the AWS Cloud. Through AWS, Amazon seeks to position itself as a “super-platform” (van Dijck et al 2018, p.16) in the education platforms and edtech industries, providing the server hosting, data storage and analytics applications necessary for third parties to build and operate platforms. These AWS integrations exceed the voice interfaces

enabled by the Alexa API. As an infrastructural super-platform, AWS coordinates a vast range of other “sectoral platforms” that depend on its servers, computing and data services for “global connectivity, ubiquitous accessibility and network effects” (van Dijck et al, 2018, p.15).

The role of AWS in platforming the edtech industry is multifaceted, from back-end server hosting and data storage to more active involvement in startup development. The AWS EdStart program is an edtech “accelerator,” “designed to help entrepreneurs build the next generation of online learning, analytics, and campus management solutions on the AWS Cloud.”<sup>15</sup> Through EdStart, AWS provides the underlying technical, social and financial architecture that enables edtech startups to build and scale products and services, as signified by its marketing slogan “Build your EdTech startup on AWS.” EdStart establishes startups on AWS with membership benefits including technical training and advice on AWS, networking and mentorship opportunities, promotional credits for eligible AWS services, the awarding of micro-credentials and “badges,” and marketing and promotional support. In addition, the EdStart Collaborators group is comprised of industry experts to provide guidance, resources and networking opportunities for members of the accelerator, and includes other edtech incubator and accelerator programs, innovation labs and venture capital investment firms.<sup>16</sup> Successful EdStart members may also be invited to become part of the EdStart Global Founders community, “an exclusive group of AWS EdStart Members from around the globe who’ve demonstrated innovative EdTech solutions and growth on the AWS Cloud.”<sup>17</sup>

Beyond EdStart, AWS claims to be “accelerating transformation in educational technology” through a range of cloud services:

The Amazon Web Services (AWS) Cloud enables education technology (EdTech) companies to accelerate development of scalable and secure technology solutions that support students and educators every day. AWS helps EdTechs realize the full potential of cloud computing with dedicated business and technical resources to support growth. From idea to IPO and beyond, AWS supports EdTech to start, grow, and optimize their business as they deliver on their mission for education.<sup>18</sup>

Many of the globe’s largest and most highly capitalized edtech companies and education businesses are integrated into AWS. It lists more than 50 AWS Education Competency Partners offering “solutions that align with AWS architectural best practices” in teaching, learning, administration, operations, and academic research.<sup>19</sup> AWS support for the edtech industry encompasses data centre and network architecture to ensure that clients can scale their platform, along with data security and other AWS services including content delivery, database, AI, machine learning, and digital end user engagement services. This complete package service that is integral to many edtech companies, enables them to deliver efficient computing, storage, scale, and reliability, and advanced features like data analytics and other AI services.<sup>20</sup>

As such, AWS has engineered structural and functional dependencies of edtech platforms and companies on its cloud architecture, acting as an integral albeit largely invisible presence in the back-

end of a growing array of edtech companies from early startups to established multinational businesses. The business model of AWS, and the detailed contractual agreements that startups must sign to access AWS services, construct new kinds of dependencies and technical lock-ins, whereby the functionalities offered by third-party education platform companies can only exist according to the contractual rules and the cloud capacities and constraints of AWS. The AWS business model thus functions partly as a normative vision of how education should be organized and function—through an intensifying accumulation of platforms all integrated and synchronized with AWS for automated data capture, analytics, and advanced AI functionality (Gulson, Murphie and Witzenberger, 2021). Through its platforming operations, AWS governs the edtech industry by delimiting the possible functions and services that companies can provide to educational institutions, operating as a catalyst and accelerator of transformation in edtech and ultimately by re-tooling the industry for expanded scale, computational power, and data analytics functionality. In turn, these platform operators are enabled to enact new techniques of governance in institutions and over the practices of educators and students, by installing AWS-powered platforms that can redefine the practical forms of education that can take place (Decuyper et al, 2021). Beyond acting as an infrastructural super-platform governing other education sectoral platforms, AWS also actively seeks to migrate educational institutions entirely to its cloud architecture.

### 5) *Re-infrastructuring*

A key objective of AWS in education appears to be to facilitate the complete transferral of an institution's digital applications, servers, and databases to its cloud. It does so through a bundle of AWS Migration services, and by providing institutions with a suite of data analytics, AI and machine learning functionalities.<sup>21</sup> Migration to the AWS Cloud constitutes a profound *re-infrastructuring* through which an institution becomes significantly dependent upon the techno-economic architecture of Amazon. One promise for institutions is increased power to use data to make all processes, events and activities more intelligible and actionable, and thus more governable (Amoore, 2020). As such, AWS may not only govern how educational institutions collect and use data, but how institutions can govern their students, staff, and estates.

Exemplifying this vision of infrastructural governance, official AWS documentation promises that by “using the AWS Cloud, schools and districts can get a comprehensive picture of student performance by connecting products and services so they seamlessly share data across platforms”:

The AWS Cloud frees schools and districts from the distractions of managing infrastructure.... With the AWS Cloud, schools and districts can access industry-shaping technology at an affordable cost, no matter the scale. From back-end data management to virtual desktops, AWS offers tools so that every student gets the attention they need to thrive.<sup>22</sup>

As part of this outsourced infrastructure, AWS also promotes Machine Learning for Education to “identify at-risk students and target interventions” and to “improve teacher efficiency and impact with personalized content and AI-enabled teaching assistants and tutors.”<sup>23</sup> This seamless introduction of AI and automation is characterized by the formation of “data lakes”—a repository

that hosts multiple types of data for machine learning analysis and visualization in the cloud (Nanjiani, 2020). The process of “architecting a data lake” involves the deployment of multiple AWS products and functionalities, including those for pulling data seamlessly from student information and learning management systems, and for handling the “machine learning workload” of analysis (Jordan and Berkley, 2020). Once the migration begins, multiple micro-services and components work in unison to automatically search for and locate data sources, identify data formats, and then suggest “schemas and transformations,” all occurring without any scrutiny or agency from the client institution.<sup>24</sup> These examples indicate how AWS promotes full infrastructure migration to the cloud in terms of making everything from students and staff to estates and operational processes more intelligible from data, and thereby more amenable to targeted action or intervention.

The re-infrastructure process through the formation of data lakes has been described as an “operational paradigm shift” with serious political ramifications as institutions lose autonomy and control over infrastructure and data (Fiebig et al, 2021, p.1). Valuable information and knowledge formerly contained by in-house IT systems vanishes inside external, black-boxed cloud systems. Institutions’ abilities to audit or implement privacy, ensure data protection compliance, or obtain meaningful informed consent for data collection and use are limited and constrained when they employ cloud operators. Clouds introduce new capacities of data analysis, AI and algorithmic intervention that may shape and steer educators’ practices and students’ learning experiences. Clouds may exert control over curricula and govern the “means of study” (Fiebig et al, 2021, p.7) by determining what kinds of educational tasks are possible to implement, circumscribing what learning outcomes can be measured, and by automatically identifying targets to be acted on.

Thus, through cloud migration and data lake architecting, schools and universities are outsourcing a growing range of educational and administrative operations, and being relegated by AWS to the status of end-users. This ultimately reflects a fresh hierarchical stratification of education, with AWS and its cloud firmly on top, followed by a sprawling ecology of edtech companies that mediate between AWS and the clients at the bottom: the schools and universities that form the data lakes from which AWS derives value. Ultimately, by re-infrastructure institutions, AWS introduces a new architectural blueprint that can affect a vast range of digital functions and tasks. The AWS architecture defines what platforms for learning, teaching, administration and research can be integrated with the AWS cloud, how student data can be stored and accessed, and what analytics capacities are available to make those data intelligible and actionable for decision-making and other governance functions. Despite being highly consequential, these infrastructural rearrangements remain opaque, hidden in proprietorial “black boxes,” potentially resistant to autonomous institutional decisions, and extremely expensive and challenging to reverse (Perrotta, 2021).

## Implications

The central claim of this article is that Amazon is creating a new global connective architecture of education governance, based on the dynamic social, technical and economic interactions that underpin cloud infrastructures and platforms. To support this claim, we identify five particular

operations through which AWS is seeking to achieve “infrastructural dominance” in the education sector: expanding its techno-economic business strategies into education (inscribing); accustoming educators and students as users of AWS through dedicated training and accreditation programs (habituating); constructing new relations between institutions and AWS through APIs (interfacing); acting as a social, technical and economic host to the edtech industry and a vast industry of third-party applications (platforming); and reconfiguring and architecting the underlying digital infrastructures of institutions, in ways that displace alternative infrastructural arrangements (re-infrastructuring). The global connective architecture of education governance that AWS is constructing can function to govern various aspects of education in new ways. Rather than conventional governance by policy prescription, it governs through the introduction of an architecture of connected technologies and the capacities and constraints they place on educational practice (Williamson, 2019; Gulson et al, 2021). Four key implications of this new form of governing should form the basis of future empirical investigation.

#### *“Big tech” influence over public education*

The first implication is the growing role of multinational “big tech” companies in education, and the complex ways they are advancing longstanding reform efforts to privatize and commercialize public education (Verger et al, 2016), albeit through new techno-economic business models (Birch and Cochrane, 2021). Social scientific and legal scholarship on private platforms and infrastructures has begun to contend with their growing social, technical and economic power, particularly their implications for key functions and processes traditionally considered the responsibility of state agencies or public sector organizations (Calo and Citron, 2021; Fourcade and Gordon, 2020). As a corporate cloud company, Amazon is attempting to create market dominance and even monopoly power across a multitude of sectors and industries, raising sharp political and legal questions over the appropriate regulatory or antitrust measures to be taken (Khan, 2017; Naughton, 2021). Part of this competition is also for infrastructural dominance in education (Fiebig et al, 2021). The expansion of AWS signifies how the governance of the public sector and its institutions is becoming “increasingly dependent on the standards and conditions set by multinational corporations, challenging the interests and values of … education as a common good as it severely impacts the sovereignty of schools and teachers to organize public education” (Kerssens and van Dijck, 2021, p. 258). In these ways Amazon is gathering significant power as a “state-like corporation” (Fourcade and Gordon, 2020) with business aims and technical capacity to influence diverse education systems and contexts, at international scale, and fulfilling governance roles conventionally reserved for state departments and ministries of education (Lundie et al, 2022).

#### *Upskilling a new “cloud elite”*

The second implication concerns the particular normative orientation AWS adopts towards education. It treats education as electronic bundles of content that can be selected as simply as browsing its online store, with “personalized” recommendations based on data analysis of student performance, and largely in terms of industry upskilling. This instrumentalist view of education is evident in AWS Educate courses and curricula for developing workforce skills valued in the cloud

industry (Ralston, 2021). AWS promotes the development of a “coding elite,” a “new occupational class” of computational experts such as software engineers, infrastructure operatives, and data scientists (Burrell and Fourcade, 2021, p.5), who can advance skills in computation, algorithms, data analytics, AI and the cloud for the benefit of AWS, either as prospective employees or “tenants” of the AWS Cloud (Sadowski, 2020). As a provider of “employability” pedagogies and curricula for the cloud industry, AWS serves its own business objectives by training a new “cloud elite” with skills in the techno-economic practices of AWS. It also reinforces the notion that producing “human capital” for industry, with measurable skills attributes matched to discrete jobs and economic outcomes, should be a normative aim and purpose of education (Komljenovic, 2019), while eliding other purposes and values of education such as informed citizenship and democratic participation (van Dijck et al, 2018). Not only does AWS position cloud architecture as the technical environment in which education can take place; it treats careers in the cloud and the inculcation of cloud computing expertise as a key purpose of education.

#### *Algorithmic control of pedagogy, curriculum and assessment*

The third implication of the growing role of big tech in education is a delegation of pedagogic, curricular and assessment responsibility from the teacher to algorithmic systems, AI and automation, with unknown consequences for teacher and student experience and performance (Selwyn et al, 2021). The current effects of the information infrastructures and statistical techniques developed to govern education systems in the US and elsewhere are well documented, including curriculum standardization and test-based accountability (Anagnostopoulos et al, 2013; Grek et al, 2021). These techniques are now evolving into governance of pedagogic, curricular and assessment practices by algorithms powered by advanced digital architectures and signifying a “shift of responsibility from the teacher, the school leader or the bureaucrat to the algorithm, the new automated manager who makes decisions for organisations and institutions” (Souto-Otero and Beneito-Montagut, 2016, p.22). The connective architecture of AWS represents the delegation of responsibility for public education pedagogy, curriculum and assessment to Amazon and its integrated infrastructure of automation, algorithms, and data analytics in the AWS cloud. More generally, AWS in education figures as a normative template for how education might evolve in relation to platforms, datafication and AI, with public education systems potentially distributed to a range of private technology providers, and held together more by connective architectures than by current administrative arrangements.

#### *Reframing education policy as programmable code*

The final implication relates to a reframing of the ways education policy is made and enacted. From an education governance perspective, Amazon is an example of a node in network governance (Lewis, 2020), where AWS can be seen as a policy actor engaged in various networks and roles. However, AWS is also creating new ways of governing that derive from a fusion of technological developments and policy enthusiasm for the capacities of advanced, proprietary information technologies, big data, and AI to provide intelligible and actionable knowledge for policymaking (Gorur et al, 2019). State agencies and departments are increasingly “cyberdelegating” responsibility

for digital services and data processing to “state-like corporations” (Fourcade and Gordon, 2020). Amazon’s cloud architecture creates and embeds a computational political rationality where programmable computer code rather than deliberative politics and automation rather than dialogue become the mode by which policy is both created and implemented (Gulson et al, 2021). As such, the continuing expansion of AWS into education, through the connective architecture we outlined, might substitute existing models of governance and policy implementation with programmable rules and computer scripts for action that are enacted by software directly within classrooms rather than mandated from afar by policy prescriptions and proscriptions. As a state-like corporation with international reach and market ambitions, AWS is exceeding the jurisdictional authority of policy centers to potentially become the default digital architecture for governing education globally.

## Conclusion

In this article we open up the Amazon corporation and its cloud computing subsidiary AWS to analysis as an emerging actor in processes of educational governance. We articulate how AWS is constructing a connective architecture of technologies and practices that are influencing diverse aspects of education systems. In practical terms it is entirely plausible that Amazon could simultaneously act as a landlord from which educational institutions can rent data storage and services, store an institution’s entire “data lake” on its AWS cloud, offer data analytic functionality for institutional decision-making, provide an API so that students can use a conversational interface to communicate with educational services, present a third-party education platform with artificial intelligence capabilities to offer predictive student analytics, and provide specific AWS content for inclusion in curricula. In the conceptual framing we develop, the AWS connective architecture impresses on the education sector a particular techno-economic business model of both data and rent extraction; habituates educators and students to particular ways of working with the cloud; configures interfaces that circumscribe forms of interaction between constituents of education; acts as an infrastructural underlay to the education technology and platform industry, reshaping the technological foundations and possibilities of the third-party products used by schools and colleges; and re-infrastructures institutions by migrating their existing digital applications and data systems to the AWS cloud, thereby introducing new cloud capacities of computation, data analytics and artificial intelligence into educational institutions and practices.

AWS has achieved unprecedented corporate penetration into education, positioning it advantageously to influence schooling, higher education, and lifelong learning in coming years. But educational research is only just beginning to grasp its main modes of operation and their implications. Our analysis identifies and conceptualizes some of these operations and their consequences, but is limited by a lack of existing concrete cases detailing how it operations manifest in educational practice.

The next step should involve detailed empirical interrogation of these operations in action, taking the framework we offer here as the basis for studying AWS at scales ranging from its global techno-economic market power in education, to the micro-practices that its architecture makes possible, and

its long-term impact on education systems, institutions and practices. Further studies will be necessary to analyze and understand the situated practices and effects of expanding corporate influence of “big tech” and other platforms in context-specific settings (Pangrazio and Sefton-Green, 2022). Ethical issues, such as privacy, consent, algorithmic bias and data-based discrimination, also remain to be examined (Hakimi, Eynon and Murphy, 2021). Moreover, Amazon’s pursuit of infrastructural dominance in education might warrant the same kind of political and regulatory attention that global technology are already experiencing for their impact on economies, societies, and democracies (Naughton, 2021). As a corporation with the reach, wealth and infrastructural power to challenge state authority over education, Amazon is positioning itself as the underpinning architecture to facilitate the governance of education systems, institutions, and practices at a global scope and scale.

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## Notes

<sup>1</sup> References to AWS webpages appear in endnotes. Authored AWS documents, such as company blog posts, are cited in the text.

<sup>2</sup> AWS Cloud Solutions by Industry: <https://aws.amazon.com/industries/?hp=tileandtile=industries>.

<sup>3</sup> AWS Cloud Computing for Education: <https://aws.amazon.com/education/>.

<sup>4</sup> AWS Educate: <https://aws.amazon.com/education/awseducate/>.

<sup>5</sup> AWS Educate Impact Stories: <https://pages.awscloud.com/rs/112-TZM-766/images/AWS%20Educate%20Impact%20Stories.pdf>

<sup>6</sup> AWS Cloud Career Pathways and Badges: <https://aws.amazon.com/education/awseducate/pathways-and-badges/>.

<sup>7</sup> AWS Educate Job Board: <https://aws.amazon.com/education/awseducate/aws-educate-job-board/>.

<sup>8</sup> AWS Skill Builder: <https://explore.skillbuilder.aws>.

<sup>9</sup> AWS Skills Center Seattle: <https://aws.amazon.com/training/skills-centers/seattle-skills-center/>.

<sup>10</sup> Amazon Alexa Skills. Education and Reference Tag:

[https://www.amazon.com.au/s?bbn=4931596051andrh=n%3A4931595051%2Cn%3A5109049051andcqid=1620369281andrnid=4931596051andref=lp\\_4931596051\\_nr\\_n\\_3](https://www.amazon.com.au/s?bbn=4931596051andrh=n%3A4931595051%2Cn%3A5109049051andcqid=1620369281andrnid=4931596051andref=lp_4931596051_nr_n_3).

<sup>11</sup> Amazon Alexa Education Skills: <https://developer.amazon.com/en-US/alexa/alexa-skills-kit/get-deeper/education-skills>

<sup>12</sup> AWS Alexa in Higher Education: <https://aws.amazon.com/education/alexa-edu/higher-education/>.

<sup>13</sup> AWS API Gateway: <https://aws.amazon.com/api-gateway/>.

<sup>14</sup> AWS Partner Network: <https://aws.amazon.com/partners/>.

<sup>15</sup> AWS EdStart: <https://aws.amazon.com/education/edstart/>.

<sup>16</sup> AWS EdStart collaborators: <https://aws.amazon.com/education/edstart/collaborators/>.

<sup>17</sup> AWS EdStart founders: <https://aws.amazon.com/education/edstart/founders/>.

<sup>18</sup> AWS Accelerating Transformation for Education Technology: <https://aws.amazon.com/education/ed-tech/>.

<sup>19</sup> AWS Education Competency Partners: <https://aws.amazon.com/education/partner-solutions/>.

<sup>20</sup> AWS Case Study: Coursera: <https://aws.amazon.com/solutions/case-studies/coursera/>.

<sup>21</sup> AWS Higher Education: <https://aws.amazon.com/education/higher-ed/>.

<sup>22</sup> AWS K12 and Primary Education: <https://aws.amazon.com/education/K12-primary-ed/>.

<sup>23</sup> AWS Machine Learning for Education: <https://aws.amazon.com/education/ml-in-education/>.

<sup>24</sup> AWS Data Lake Solution: <https://docs.aws.amazon.com/solutions/latest/data-lake-solution/overview.html>.

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