Current and Future Issues in Learning, Technology, and Education Research

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Contents

Executive Summary

A sea change in society driven by technology presents both opportunities and perils for education and research, especially with respect to equity and human flourishing. It is urgent that scholarship must adapt to address this challenge.

Four major developments in technology promise to fundamentally alter society: the rise of pervasive or “total” data, platforms for realistic “retina-grade” experiences, deployment of artificial intelligence and other algorithms for processing big data, and the increasing ubiquity of technology access but with digital divides.

These lead to six key areas of tension regarding technology and education; (1) Ownership, governance, and adoption of information and curricular content; (2) Ownership and control of educational data; (3) Personalization vs. standardization of educational experiences and assessment criteria; (4) Nature of knowledge and learning as contested ground; (5) Improvement vs. disruption of educational institutions; and (6) Bottom-up vs. top-down design.

Addressing the tensions requires additional effort in several areas. We need to better understand how technology intersects with holistic conceptions of human learning and thriving. We need to study and develop new models for how technology shifts the role and preparation of educators and educational leaders. We need targeted, actionable research on how educational technologies advance or curtail equity, along with better understandings of how to design technology in support of justice. And, we need to transform our research methodologies to encompass technological possibilities without sacrificing context, quality, or ethics. To support progress in these areas, researchers, designers, and educators must: commit to shared prosocial values and equity; develop new, integrative methods for research and design; and create new relationships and structures to support research, development, and enactment.

Keywords: cyberinfrastructure; cyberlearning; education; social justice; technology

Current and Future Issues in Learning, Technology, and Education Research

We are now deep in an era of "cyberlearning," which denotes both a greater degree of technology as well as a qualitative shift in the way technology and education are intertwined. Particularly since the advent of the Internet, we are watching increasing micro-revolutions of what happens to learning when new forms of technology are introduced. Claims of technology enabling revolutions in education are not new and predate information technology like computers. This era is marked by a series of important sea changes in education driven by technology—differences in kind and not in degree. Similar to cyberinfrastructure as technologies that become essential infrastructure for society in realms such as government, energy, or health, the cyberinfrastructure of education—what one might now call cyberlearning—will in short order become taken for granted. Indeed, the shifts education undertakes now as technology becomes an essential infrastructure for learning will shape educational institutions and human society for generations to come.

This report presents working definitions of relevant ideas like "technology," "education," and "learning," as well as shows how new capabilities in technology are creating seismic shifts both in society and in learning. As we explore emerging tensions in how these technological shifts are influencing education and learning, we propose specific areas in which educational research and development are needed to explore technology's impact on learning and help shape it going forward.

To organize our recommendations, we draw on four focus areas identified by the Spencer Foundation: exploring human learning and thriving; developing high-quality educators and leaders; cultivating equitable educational spaces; and innovative research methods. We identify four major developments in technology that are producing qualitative shifts in the education landscape: total data; retina grade experiences; artificial intelligence and other algorithms for processing big data; and an increasing ubiquity of technology but with digital divides.

According to a National Science Foundation report, "cyberlearning" means "learning that is mediated by networked computing and communications technologies" (Borgman et al., 2008). The term cyberlearning is relatively new and builds on the concept of cyberinfrastructure (Stewart et al., 2010), denoting increased pervasiveness of and reliance on technologies (in this case, infrastructure for learning). That increase is not just in terms of a greater degree of technology use but in terms of a qualitative shift in the way technology and education are intertwined. Building on this distinction between more general notions of educational technology and more transformational ones, the Center for Innovative Research in Cyberlearning (CIRCL) defined cyberlearning as "the use of new technology to create effective new learning experiences that were never possible or practical before" (CIRCL, n.d.). However, in recent years the pace, depth, and influence of technological adaptations in society warrant inspecting educational technology not as a "bolt-on" change to educational systems

(Cuban, 1986), but as profound shifts to how and what people teach and learn (Collins & Halverson, 2009; Hoadley & Kali, 2019; Roschelle et al., 2000).

This report explores these issues in five sections. First, we lay out our working definitions of relevant ideas like "technology," "education," and "learning." Second, we examine four ways that new capabilities in technology are creating seismic shifts in society, and in learning. Third, we explore emerging tensions in how these technological shifts are influencing education and learning. Fourth, we propose specific areas in which educational research and development is needed to explore technology's impact on learning and help shape it going forward, based on the four thrusts identified by the Spencer Foundation in their recent field engagement process. Finally, we examine the moment in which we live, including how COVID-19 is impacting these issues, and the potential roles that can be played in the process of researching and designing effective technology use in education.

Major Developments and Tensions in Education and Technology

Four Major Developments in Technology

1. Total data
2. Retina grade experiences
3. Artificial intelligence and other algorithms for processing big data
4. Increasing ubiquity of technology, but with digital divides

Six Key Tensions Regarding Technology and Education

1. Ownership, governance, and adoption of information and curricular content
2. Ownership and control of educational data
3. Personalization vs. standardization of educational experiences and assessment criteria
4. Nature of knowledge and learning as contested ground
5. Improvement vs. disruption of educational institutions
6. Bottom-up vs. top-down design

Approach

Given the scale of this report, first we outline our perspectives on various relevant issues, including how we orient to education and learners, and technologies and technology users. For the purposes of this report, we approach *learning* in ways largely consistent with the learning sciences and critical perspectives of education. Thus, we think across cognitive, sociocultural, and sociopolitical lenses on learning (Danish & Gresalfi, 2018; Politics of Learning Writing Collective, 2017). We understand learning as a process by which individuals acquire, practice, and hone new knowledge (Bransford et al., 2000) through participation in socially mediated, collective activity (Brown et al., 1989; Lave & Wenger, 1991). In any consideration of learning, we recognize that power, politics, ethics, and equity shape learners' experiences and trajectories (e.g., Esmonde & Booker, 2017). Knowing this, we resist deficit conceptions of learning where researchers and designers "approach an individual as damaged and the learning process as one of repair" (Uttamchandani, 2018, p. 481). Instead, we embrace culturally responsive and culturally sustaining approaches that position learners through an asset-oriented lens (Ladson-Billings, 1995; Paris, 2012).

Within this perspective, education is the process by which people deliberately support learning, including not only traditional formal primary, secondary, and tertiary schooling, but also activities such as workplace training, self-study, apprenticeship, informal learning environments such as museums, and so on. Thus, we think about education variously as a social good, a critical practice of freedom, a pathway towards one's future opportunities, and a cultivation of the self (e.g., Dewey, 1897; Freire, 1972). Importantly, this kind of educational practice does not just take place during the school day. Rather, such learning is "life-long and life-wide" (Banks et al., 2007; Bell et al., 2009). Youth and adults encounter such opportunities outside of school, as in afterschool clubs, hobby activities, workplaces, and the Internet (Gee, 2018; Ito et al., 2013; Peppler, 2017; Resnick, 1988).

These expansive definitions of learning and education are vitally important to understand our perspective on technology's impact, as much of the technology world may often use narrower definitions, such as narrowing learning outcomes of technology to cognitive impacts such as recall of facts or performance of skills, or narrowing ideas about educational technology to only those applications which exist within a formal K-12 or university setting in support of explicit curricular goals. Without a broader definition, one might overlook the importance of, for example, makerspaces, YouTube communities of interest, or even social media in transforming learning (and therefore in exerting pressure on the institutions of formal schooling to adapt accordingly).

For the purposes of this report, we approach *technologies* with a focus on information and communication technologies (ICT), particularly those enabled by computing. Technology can be appropriately defined as any invention or tool that helps humans accomplish things, including cultural practices, techniques, crafted objects, and more. Indeed, anything from a broom to long division to queuing in lines could be thought of as a technology. In this report, however, we focus on the technologies that align with the earlier definition of cyberinfrastructure, that is, digital technologies that are part of a transformative and increasingly ubiquitous infrastructure for modern life. Examples could be an app, the Internet, or a smart phone, but could also include sociotechnical systems enabled by ICTs, such as a company and network of universities providing MOOCs (Massive Online Open Courses), or an informal network of learners facilitated by social media. Thus, we focus on but are not limited to digital "things" like hardware or software, as well as the broader connected human inventions such as business models, organizational structures, and so on.

There are numerous and contradictory ways that technology is conceptualized in its impact on society. "Technological determinism," for example, refers to the assumptions that technological changes are the most important driver of social changes, that is, that changes in technology determine the flow of all changes in human social behavior. In contrast, a more technology-neutral perspective instead focuses on how human agents use technology to advance pre-existing goals and desires and minimize the impact of the technology itself, that is, it focuses on technology as a tool used by humans rather than a driver of human activity. Several theoretical stances such as cultural-historical activity theory, actor-network theory, communities of practice theory, and social construction of technology theory frame alternatives to the simpler notions of tech driving people or people driving tech (Oliver, 2011). In this paper, we understand technologies as mediators that shape actors' perspectives of their goals and activities while also being used by actors to achieve those goals.

As applied to education, this range of perspectives can lead to rapidly different ways of focusing and using technology. Taking the stance of proponents of education, we center an agentic, design-friendly view in which aims and impacts of technology can be viewed as aligned or misaligned with societal goals; that is, we not only describe or observe technological impacts but also judge them. For the purposes of this report, we draw on Toyama's (2015) metaphor of technology as an *amplifier*, that is, "that learning technology can take an aspect of a learning process and emphasize it, refine it, intensify it, and scale it widely. This can be good or bad; undesirable or desirable effects on learning can scale with equal ease" (Roschelle et al., 2020, p. 1).

An asset- or resource-based perspective to learners allows us to elevate *people* (and learners specifically) as users of technologies, rather than passive consumers of technologies, who have some agency and power as they navigate socially and technology-mediated life. Of course, we recognize that people's agentic practices are happening at the interface of social systems that are highly unequal. For example, technologies might be used by power players to surveil, punish, and incarcerate, as with facial recognition technology when used by police (Lasalle & Thompson, 2020; Rahman, 2020). These practices also take place in the sphere of education in explicit and subtle ways, such as through the use of proctoring software, plagiarism detection tools, and misleading engagement metrics such as "screen time." In so far as these dignity-robbing social practices are amplified by technology, they become entrenched in ways that are difficult to resist. However, learners *do* resist inequitable uses of technology (e.g., Kelly, 2018; Stornaiuolo & Thomas, 2018). Remembering this, we seek to understand and value these endogenous uses of technologies.

We assert that, increasingly, technological change is *always* a backdrop for education. Of any social practice, one can interrogate its technological dimensions and specifically how technology amplifies or restricts the practice. Moreover, given the rapid pace of technological change, we can see that this change itself exerts pressure on how practices evolve over time. Thus, any rigorous attention to education cannot ignore technology. While technology need not always be foregrounded in research—indeed, sometimes this obscures the social practices at hand under a veil of technological sophistry—education researchers need a scale of literacy around technological issues that is not yet shared in the education research community. Importantly, we argue that everyday life is now intertwined with technological innovation at such a scale that ignoring technology's amplifying quality is likely to create more inequities. Researchers and designers of technologies and of education cannot claim that the ethical responsibility to understand this amplifying effect is not relevant and should not enclose research.

The changes technology is likely to have on education are profound. As we move forward, there are unresolved tensions this technological amplification runs up against for educational uses. Indeed, this increasing technological use could significantly ameliorate inequities—or amplify them. It depends on what we, as educationists, researchers, designers, funders, and citizens, do next . . . *and* how deliberate we are about what we do, why we do it, how we do it, and how we talk about it. The possibility exists to generate large scale critical technological literacy in the community of technologists, funders, educators, and researchers that in turn is key to delivering on the oft-made promises of technology as a tool for social improvement. We now turn our attention to these technological changes, their possibilities, and their tensions.

Four Major Developments in Technology

We identify four major developments in technology that are producing qualitative shifts in the education landscape: total data, retina grade experiences, artificial intelligence and other algorithms for processing big data, and increasing ubiquity of technology but with digital divides. These developments are quite obviously not the only important ways technology is advancing, but they capture some of what presages societal shifts even more pronounced than what we have already experienced with digital technologies in the late twentieth and early twenty-first century. While trend reports might identify other technological trends that will impact society (e.g., space exploration, bioengineering, advanced robotics; see Future Today Institute, 2020), these four overarching areas of technological advancement are the ones we see as predominantly shaping the education ecosystem in the next few decades.

Total Data

Technology will soon enable nearly comprehensive data collection on every aspect of human activity. This is driven by a combination of trends, including cheap data storage (Mearian, 2017), inexpensive and ubiquitous sensor-rich devices that are increasingly interconnected (such as mobile phones, doorcams and dashcams, smart-speaker digital assistants, roadway automatic toll systems, or wearable health devices), and the increase in digital mediation of mobility, commerce, media, and communication (e.g., digital television services, online shopping, texting and videoconferencing, and so on). An example many people will be familiar with is the rise of digital photography. Early on, photographs in the form of data were costly to acquire and maintain, either requiring expensive scanning technology or pricey specialty digital cameras. The advent of the photoCD format from Kodak allowed film pictures to be processed and scanned simultaneously and provided in an archivable format. This was a big advance but still more significant was the creation of mobile phone-based cameras and online photo sharing systems. Through these technologies, pictures became such a matter of course that one might not only take pictures of significant events, but also photograph as a method of notetaking or social networking. “Pics or it didn’t happen” is a phrase that would not have made sense as recently as 2005. Now, all major commercial online service providers (Google, Amazon, Facebook, etc.) not only provide the capability to store photos as fast as you can take them, but also make it trivial to share them, and increasingly to subject them to advanced processing ranging from visual enhancement to face recognition to compositing with others’ photos for building 3D models of public spaces (Hwang et al., 2012).

Other forms of data are becoming more and more fine grained and accurate; for instance, personal health wearables are moving from rough measures such as estimated “steps” to medical-grade heart rate monitoring. Such trajectories exist in many areas of digital data: first comes initial, halting steps from analog to digital collection, storage, and dissemination; then, development of infrastructures (both user-facing and back-end systems) to integrate the digital data into human practices; next, greater automaticity and higher resolution “filling in” the data; and finally reliance on the data not only by its traditional stakeholders but others such as businesses, governments, and so on, with often unanticipated consequences.

More and more forms of data are moving into the final stages of these trajectories, where more and more fine-grained data are increasingly being collected, shared, and used. For example, projects in “lifelogging” are able to do things such as attempt to record every photo a person takes through their lifespan, every utterance of a human lifetime, or longitudinal healthcare information. We also already take for granted the idea that commercial advertisers might track our activities online, surveilling our reading behavior as we hop from website to website, but increasingly this can be linked to other behavioral data such as purchasing through credit card transactions, or coordinating physical location with virtual behavior through GPS or other locative data (Liao, 2018).

Thus, we see in this “total data” phenomenon a convergence of trends towards more digital data, at a more fine-grained level, shared more widely, and collected more ubiquitously and comprehensively. In education, the collection of such all-encompassing data raises the possibility of charting and reacting to every microgenetic moment in learning, or of creating previously unthinkable forms of assessment and credentialing, as well as raising the spectre of oppressive surveillance.

Retina Grade Experiences

Technology permits the production of sensory experiences that are increasingly realistic, to the point where they are as realistic, immersive, and comprehensive as the real world itself. In 2010, Apple introduced a phone with a “retina display” which had a high enough resolution that, for users with 20/20 vision holding the phone at a typical distance from the eye, the resolution of the display exceeded the resolution of the human retina to distinguish individual pixels. As a metaphor for other sensory modalities, what we term “retina-grade” can be used to describe synthetic experiences that saturate the input range of the human perceptual system.

While virtual reality that is indistinguishable from real experience is still not available (for instance, we have very limited technologies to synthesize smells or touch), the latest technology-based output devices are able to create compelling sensory experiences, and advancements are taking place rapidly. Some, akin to *Star Trek's* holodeck, utilize the natural human sensorium, with immersive virtual reality headsets (like Oculus Rift), augmented reality glasses (like Google Glass), or highly tailored audio synthesis, recording, and playback systems (like Apple's Airpods Pro). These technologies are able to create experiences that mirror natural perception in ways that are striking. Others attempt to bypass the human perceptual organs entirely, as with cochlear implants for restoring hearing to those whose auditory apparatus cannot register acoustic signals. Such innovations raise important philosophical questions about the reality of experience (Chorost, 2005).

These realistic experiences may be produced in the real world (e.g., an IMAX film without any computer-generated imagery or CGI), may be entirely synthetic (e.g., a video game sequence created without motion capture or photographic digital assets), or a mix of the two. Where in the past, people had a reasonable sense of which mediated experiences were fake or real, the ability of audiences to determine whether something is synthetic or recorded, manipulated or not, or even whether it is mediated by technology or not is eroding. Furthermore, based on what we know of the neural plasticity of the mammalian perceptual system, it is possible to conceive of technologies that "display" visual or other sensory experiences that could potentially reshape what "seeing" (or hearing, or feeling) really is (e.g., "transhumanists" who extend human senses through body modification or sensory augmentation: Pearlman, 2016; Reilly & Vintiner, 2021; Robertson, 2017). In the field of education, we may be moving towards a time in which the instructional designer or teacher has as their palette literally the entire set of possibilities of the human perceptual system, being able to synthesize any learning experience whether realistic or not.

Artificial Intelligence and Other Algorithms for Processing Big Data

Artificial intelligence and new algorithms for handling massive datasets allow unprecedented inferencing about, responding to, and shaping of human behavior on a massive scale. Artificial intelligence has numerous definitions; one helpful one is that AI is "a branch of computer science that studies the properties of intelligence by synthesizing [producing] intelligence" (Stanford University, 2016, p. 13). In our context, the most important aspect of artificial intelligence is how it reflects a move towards technology that can make technology "function appropriately and with foresight in its environment" (Nilsson, 2010, xiii). The Computing Research Association identifies three major functional areas developing in AI research: integrated intelligence, meaningful interaction, and systems that "learn" or modify their own programming (Gil & Selman, 2019). Integrated intelligence refers to the ability to take systems that model particular kinds of knowledge or intelligence and to integrate them (e.g., combining a computer vision system that does optical character recognition with a machine translation system that can take that text and translate it into another language). Meaningful interaction refers to the ability to make computers collaborate more effectively with people and/or provide interfaces that are more natural for people, including things like speech-based intelligent personal assistants, predictive text editing, gesture recognition systems, and so on. Systems that "learn" (what Gil and Selman call "self-aware learning" systems) refers the ability of AI to infer and acquire knowledge directly without it being preprogrammed; this can include everything from using machine learning techniques to make inferences from big data, to software observing and imitating human behavior, to a robot exploring an environment to make sense of it. While there are significant barriers to the kinds of everyday depictions of sentient or superhuman AI in pop culture, AI's ability to mimic intelligent behavior represents a key area of technological advancement that has potential to change or is already changing the nature of many human activities.

As AI advances, so does the ability of technology to not only perform specific tasks but to radically change the types of technology-enhanced tasks people can do. This in turn shifts the ways in which knowledge and knowing are distributed and externalized. In some cases, AI will indeed replace humans as AI systems perform tasks previously done by people (whether task-specific AI, such as self-driving cars, or more general AI, such as general systems for medical diagnosis, research, business intelligence, etc.). But, other tasks still performed by humans will instead shift in response to support from AI (for instance, working in conjunction with "intelligent assistants"). And, AI magnifies the impact of both total data and retina-grade interfaces by providing the means to link the two (e.g., "deepfake" videos; Victor, 2021; Wu et al., 2021).

Given increases in "total data," advances in AI have included developments in algorithms useful for processing big data, including everything from natural language processing algorithms to machine learning to computer vision. Doing so offers new opportunities for researchers to make sense of data traces that previously were impossible to capture or analyze. In education, such sense-making has been advanced by the field of educational data mining and learning analytics (e.g., Baker, 2010; Lang et al., 2017). However, outside of education, algorithmic black-boxing has been shown to sometimes produce harmful, racist, and other deleterious effects (e.g., Benjamin, 2019; Eubanks, 2018; Noble, 2018; O'Neil, 2016). Thus, moving into the future more work must consider the ethical dimensions of "should we" alongside "can we" when deploying innovations based on such big data processing algorithms.

The implications of these advances in AI for education include not only changing what people need to learn in a radically different labor market but also potentially shifting the relationships between learners, teachers, and information through mediation by intelligent tutors or other personalizable learning tools. As Roschelle et al. (2020) argue, with respect to learning, AI can inspire new design concepts that “expand beyond familiar ideas of technology supporting ‘personalized,’ ‘adaptive,’ or ‘blended’ learning” (p. 8). They offer five new design concepts to understand AI’s interaction with learning: (a) orchestrating, where AI can support students and teachers in coordinating learning activities, including shifts between activities and planes of activity (e.g., whole class to small group to individual); (b) augmenting human intelligence, where AI can help teachers by better understanding their goals and plans, and offering information that can aid the teacher in effective decision-making; (c) expanding naturalistic language, where AI recognition can create spaces where learners can participate in learning through more language repertoires and gestures or other embodied actions in ways that create more opportunities for learners to understand, dialogue, and demonstrate understanding; (d) broadening competencies, where AI can support and assess new learning goals such as collaborating or becoming comfortable with a particular mobile technology; and (e) revealing connections and equivalences, where AI can help illuminate important learning patterns and pathways that have not yet been visible, for example how seemingly unrelated learning experiences in one grade level might shape learning experiences in another grade level. Together, this expanded repertoire of metaphors illuminates the range of ways that increasing technology proficiency and adoption of AI technologies might shape and change practices of learning.

Five New Design Concepts in AI and Learning (Roschelle et al., 2020)

Orchestrating activity

Where AI can support students and teachers in coordinating learning activities, including shifts between activities and planes of activity.

Augmenting human intelligence

Where AI can help teachers by better understanding their goals and plans, and offering information that can aid the teacher in effective decision-making; Expanding naturalistic language.

Expanding naturalistic language

Where AI recognition can create spaces where learners can participate in learning through more language repertoires and gestures or other embodied actions in ways that create more opportunities for learners to understand, dialogue, and demonstrate understanding.

Broadening competencies

Where AI can support and assess new learning goals such as collaborating or becoming comfortable with a particular mobile technology

Revealing connections and equivalences

Where AI can help illuminate important learning patterns and pathways that have not yet been visible, for example how seemingly unrelated learning experiences in one grade level might shape learning experiences in another grade level.

Increasing Ubiquity of Technology, but With Digital Divides

Information and communication technologies writ large reach nearly the whole human species, with over half of all people worldwide using the Internet, but important disparities still exist in access. According to the International Telecommunications Union (ITU, 2019), 2018 is the year in which more than 50% of the world became Internet users, and the penetration of other global communications networks (most notably, mobile phones) was greater still, meaning most people worldwide have access to information that was previously impossible. Increasingly, users do not need a computer to access the Web, instead using mobile broadband—current statistics show that, especially for low-income populations around the world, broadband Internet via mobile phone reaches a much greater percentage of people than fixed line broadband such as cable or fiber optic networks to the home or office.

However, being an Internet “user” is a very minimal definition of access, and that access is inequitably distributed. The ITU (2019) points out that most of the offline population lives in the “least developed” countries; that the gender gap in access is increasing and only a quarter of countries have gender-equitable use of the Internet; and that both bandwidth and IT skills are barriers to Internet use. In addition, many groups face other barriers to using information networks, for reasons ranging from lack of resources in their home language, to censorship from government regimes, to lack of accessibility for persons with disabilities.

Nonetheless, this ubiquity of networks is a platform for increasing ubiquity of technologies whether or not they are part of an individual’s Internet use. Network-enabled technology infrastructure may influence users without access to Internet browsing; for instance, satellite-based surveying may allow rural development in areas without a physical network infrastructure; facial recognition technologies may allow surveillance of people who don’t have smartphones. As the network becomes more ubiquitous, people are influenced more by global technology infrastructure even if they never touch a phone or Web browser.

Notwithstanding barriers to access, the tipping point of having information networks that allow near instantaneous sharing of data, documents, voice, images, and videos are having an impact on everything from the prices fishers get for their catch (Abraham, 2007) to reduction of domestic violence (Lee, 2009). In education, we can assume that limited access to information will no longer be the main reason why learning happens primarily in formal schooling, and that new possibilities for connectedness (between people, or between people and information) will make learning less time– and place-constrained and less institutionalized.

Examples of New Technologies with Profound Impact: Emotionally Responsive and Manipulating Technology

Technology can certainly affect our emotions, but increasingly, educational technologies can infer learners’ emotional states and respond to emotions strategically. Methods for inferring emotion include using textual analysis to look for “sentiments” in social media or conversations with intelligent agents, using face recognition, eyetracking, and gaze detection to infer emotions, or attempting to directly measure physiological elements of emotion using galvanic skin response, heart rate, or other bodily processes. Intelligent tutoring systems incorporating all of these inputs have been prototyped (D’Mello et al., 2007) and learning outcomes have been linked to the types of states detectable by computers (Baker et al., 2010). These types of emotional detection open up many possibilities for technologies to be emotionally responsive, for instance in responding to cognitive engagement, boredom, delight, or frustration. Theories have begun to be developed on how design of technology can support learning through creating emotional conditions conducive to learning (Plass & Kaplan, 2016). Obviously, however, there are core ethical questions associated with such technologies. While using emotional intelligence to persuade or manipulate others in humans is associated with psychopathy (Grieve & Mahar, 2010), some researchers have begun developing frameworks for ethical design of technology in this area (Davis, 2011).

Key Tensions Regarding Technology in Education

The massive changes in technology generate key tensions in how technology influences education; below, we identify six such tensions based on our own perspectives on the current technology trends. As learning technologies increasingly become a ubiquitous powerful cyberinfrastructure for learning, there are multiple issues that arise, and while the following are not either-or binaries, they are areas in which tensions and multiple future possibilities emerge. Several are related to how technology and society in general are evolving, reflecting larger social tensions around freedom and control. Some are related to the contested ground of what the aims and means of education are (or should be) as a public enterprise. And most relate to the ways in which different stakeholders in the educational technology space have different institutional incentives (e.g., the belief by Silicon Valley startup founders that disruption and market share are the path to success, vs. how the structures of public education are doubly accountable to voters and politicians, or the ways in which educational technology R&D is conceptualized and funded by public and private sectors). Below, we take each of the six in turn.

Ownership, Governance, and Adoption of Information and Curricular Content

In an information-rich landscape that includes new systems for producing and distributing curricular materials, the ownership, governance, and adoption of such content by different educational stakeholders become contested issues. Prior equilibria in the United States in which for-profit publishers, governments, and faculty had ownership of different types of content have always had some tensions (e.g., the ways in which U.S. K-12 textbook publishers would create textbooks to not offend the political sensibilities of large states like New York or Texas) but increasingly technology becomes a more contested ground. We have seen examples such as the Open Educational Resources movement which attempts to create free instructional materials to displace the for-profit educational publishers, who are in turn exploring new models of intellectual property such as renting vs. buying textbooks. Initiatives from academia to create free and open options like MOOCs (Massive Open Online Courses) have in some cases been turned into ways to capture the copyrighted course designs of individual faculty and turn them into profitable intellectual property for corporations (Aaron & Roche, 2015). Moreover, control of instructional content material also includes control of information flow. The dramatic shift from information scarcity to information plenitude evokes challenges in how schools manage information they don't directly provide. For instance, schools routinely install Internet "nanny" filters that reduce students' access to information. Teachers may or may not be restricted in what information resources they can provide to students. In moving from an information scarcity model in which a small number of authoritative textbooks were the reference to today's information overflow, educators (including not only teachers but librarians) are dealing with misinformation in the classroom (e.g., Youtube videos promoting Holocaust denial), attempts to make safe student-to-student communications and information sharing (e.g., preventing cyberbullying in social media), and more generally a loss of centralized control over the information learners access.

Ownership and Control of Educational Data

As educational data proliferates, tensions emerge over who should access, own, and control such data. One of the key affordances of using technology in education is the ability to collect and process detailed data about learners and their lives. This affordance raises questions about effective and ethical use of student learning data, and especially about who owns and controls such data. Multiple examples help illustrate this tension. American schools have handed over vast swaths of not only academic data but attendance and other information to for profit companies, with some parents pushing back (Beckett, 2019a, 2019b, 2019c) while schools in China have gone further, using facial recognition technology to police student behavior or emotions (Wang et al., 2019). Yet, attempts to consolidate data across schools for academic and research purposes have been met with failure (Bulger et al., 2017). Even where learners must consent to having their data used by others, this consent is often baked into an all-or-nothing choice of using educational technologies that require loss of privacy, or not having access to the technology at all.

Personalization vs. Standardization of Educational Experiences and Assessment Criteria

Technology affords attempts both to standardize education and to personalize or differentiate it, goals that are often in direct conflict with one another. Institutions of education have always had to contend with individual differences among learners. Whether these were considered to be worthy of celebration or problematic has varied over time. Early educational technology celebrated the possibility of standardizing not only the possibilities of teaching (to a presumably higher standard than the status quo), but also the possibilities of standardizing the educational opportunities of students, and moreover of standardizing student outcomes. Paradoxically, one of the ways in which educational technologies have aimed to standardize the learning outcomes of students is by personalization, or anti-standardizing the learning experiences individuals have. In general, this approach has important limits if it assumes the computer delivers instruction rather than being part of a complex tapestry of classroom practices and routines (Enyedy, 2014). As Bulger (2016) points out, personalization ranges from any de minimis form of customization (e.g., choosing an avatar or color scheme) to fully adaptive systems that allow learners to set their own learning goals, methods, and even assessments.

Within this range of levels of personalization, it's also important to examine the goal of personalization. In some cases, personalized learning takes place in a hegemonic curriculum or assessment framework, varying primarily in instructional materials and strategies (e.g., intelligent tutors as described in VanLehn, 2011). In others, learners set the agenda (e.g., in the Next Generation Learning Challenge schools studied by RAND, 2017). An additional aspect of this tension is whether the actual personalization is driven by the technology designer, the teacher, or the learner. Finally, it is unclear how metaphors other than personalization might similarly improve individual learning trajectories in experiences where community participation and collaborative activity are primary.

Nature of Knowledge and Learning as Contested Ground

Because technologies can entrench particular activities or ways of learning, educational technologies are not agnostic with respect to the nature of knowledge and learning, and are thus an important battleground in fights over epistemologies in education. Teaching strategies in schools have been deeply contested for millennia (e.g., Socrates' concerns about written vs. oral education) but these contestations have largely been resolved in the hands of cultural norms and individual classroom teachers, who in a pre-technology world were primarily responsible for creating the learning environment and the learners' experiences, typically replicating the epistemologies in which they were schooled. However, as much of that experience either moves online or is moderated by technologies with incredible power to surveil, control, or shape interaction, the designers of software take some of this control from the teacher. Attempts to make technology "teacher-proof" sometimes emphasize didactic instruction over inquiry (Cates & Kulo, 2009).

On the other hand, other technologies are designed to support more open-ended inquiry (e.g., tools to support collaborative knowledge building communities and higher levels of learner agency; Scardamalia & Bereiter, 2006). Disconnects between teacher epistemologies and technologies may cause less technology use (Ravitz et al., 2000), or with support may lead to shifts in teacher epistemology (Becker & Ravitz, 1999; Schwarz et al., 2017). Generally, online information presents issues of information literacy and media literacy (Caulfield, 2017), which intersects with epistemological questions and questions of power and equity in schooling. Didactic technologies support didactic pedagogies which support simplistic epistemologies; inquiry technologies support inquiry-oriented pedagogy which supports a more constructivist epistemology. And, critical or postmodern approaches can suggest additional ways to consider pedagogy and technology (McLaren & Jandrić, 2015).

Improvement vs. Disruption of Educational Institutions

Paralleling Silicon Valley's commitment to using technology for "disrupting" industries, there is tension between the application of technology in education to support or bolster existing institutions and institutional goals, and using technology to disrupt (i.e., displace or replace) existing institutions and institutional goals. On the disruption side, Christensen and colleagues (2011) argue that technology should be used to change how schools might provide new personalized learning experiences to support changed or additional social goals (such as economic mobility instead of equipping students to participate in democratic institutions). Christensen, and many others in Silicon Valley, argue that the main way to force change on otherwise resistant organizations (like schools) is to significantly alter power in the marketplace. On the other side, the improvement science literature looks to see how existing institutions can use clarity of goals and indicators to innovate within existing institutional structures (Bryk et al., 2015; Lewis, 2015), and technology is often highlighted as a platform to support this kind of improvement (Piety et al., 2014; Siemens & Long, 2011). At issue is what needs to be improved vs. disrupted (i.e., replaced), ranging from goals to metrics to organizational structures, and whether systems that attempt to build on prior success or failure are better or worse than starting over.

Bottom-Up vs. Top-Down Design

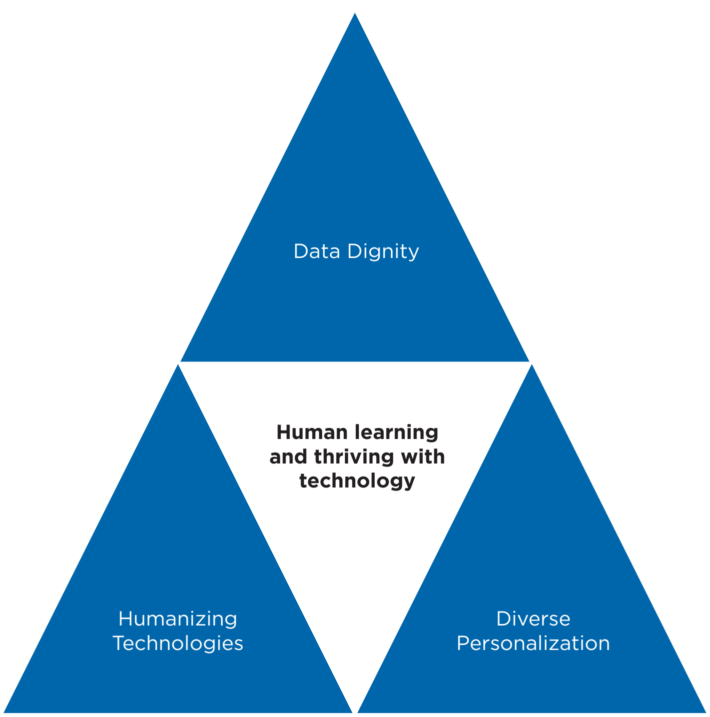
Because of the influence technology has on educational settings, the question of who designs what for whom is crucial, leading to a tension between more bottom-up participatory forms of design, vs. more top-down, experts-and-IT-department–driven design. Much as educational content can be centralized or crowdsourced, the types and affordances of technology in education might be driven more by stakeholders such as teachers (e.g., Severance et al., 2016) or children (Druin & Fast, 2002). Empowering the users of technology to actually design and build the technology builds on a tradition in computer science called "end-user design" and has been termed "meta-design" (Fischer, 2010). In this conceptualization, meta-design aligns with a culture of participation in which learners and others produce, rather than consume, technologies for personally meaningful purposes. Certainly, traditionalists might emphasize design of technology by experts simply because of the difficulty of producing technological tools, but some constituencies also recommend centralization of design of technologies to ensure effectiveness, akin to the highly centralized process by which medical interventions are designed and vetted (Romeo, 2015).

Recommendations for Areas of Investigation

Next, we apply these four developments and six tensions to make recommendations for investigation (research and design). To organize the recommendations, we draw on the four focus areas identified by the Spencer Foundation (Nasir, 2019): exploring human learning and thriving, developing high-quality educators and leaders, cultivating equitable educational spaces, and innovative research methods.

Exploring Human Learning and Thriving

Technology's role in human learning, and especially in human thriving, demands research on how learning technologies can be designed to respect the dignity, individuality, and humanity of learners. Thriving is a holistic concept, encompassing aspects of human learning and development, well-being, equity, and empowerment. Thriving can be contrasted with more school-focused conceptions of learning in that it links an individual's "competence" to their circumstances; Osher et al. (2020) define thriving as "to feel, be, and be seen as competent in multiple life domains" (p. 2) and argue that the concept can be explored not only at the individual level but at the level of communities or society as a whole. Traditional educational goals such as knowledge, skills, and attitudes, or cognitive and socioemotional outcomes, focus on the learner as an individual. In contrast, learning and development towards thriving conceive of each learner's relational status to past, current, and future circumstances. In this section, we examine three areas where technology and thriving may intersect: the use of data about learners, what counts as learning, and humanizing vs. dehumanizing technologies.



Data: Dignity, Privacy, and Ownership

Given that "total data" technologies have made it possible to collect massive amounts of data on individuals, including those as intimate as moment-to-moment physiological data (e.g., heart rate) of students, it becomes increasingly important to attune to the assent and consent processes for learner data. How much do and should learners know about how their data is being collected, stored, used, and/or sold? What purposes are legitimate uses of such data? For example, should information that supports accommodation of a learning disability be usable for discipline and behavior management? How possible is it for students and parents to "opt out" of harmful data use, especially in schools? And how do educators ensure that such "opting out" does not propagate to lower-quality learning experiences for the students that do so?

These questions are fundamentally about consensual technology. They are relevant for both researchers and commercial product designers, who are held accountable for data collection and storage in very different ways (Institutional Review Board standard human subjects research protocols vs. non-transparent internal corporate mechanisms, respectively). In explicit and implicit ways, learners are always assenting or withholding assent to learn (e.g., Erickson et al., 2007). In the field of critical informatics, Cifor and colleagues (2019) have amplified the importance of refusing to participate in "harmful data regimes" in their "Feminist Data Manifest-No." Building on critical perspectives towards data, the Manifest-No refuses "the use of data about people in perpetuity," an understanding of data "as disembodied and thereby dehumanized and departicularized," and "any code of phony 'ethics' and false proclamations of transparency that are wielded as cover, as tools of power, as forms for escape that let the people who create systems off the hook from accountability." Research outside the education space has investigated different ways to conceptualize ethical data use. For example, Singh and Vipra (2019) propose a model of community ownership of data's economic value, while Couldry and Mejias (2019) use the analogy of resource exploitation in colonialism as a way to better understand how technological data collection can manipulate individuals in unethical ways similar to unethical natural resource exploitation in a colonial system. These refusals are especially loaded with regard to educational technology in schools, where students (and sometimes teachers) are not empowered to understand what happens to their digital trace nor to refuse to use these technologies without sacrificing the quality of their learning.

What Counts as Learning: Personalization, Standardization, and Individual Differences

How educational systems decide what counts as learning can conflict with respecting learners' individuality; traditional methods for instructional standardization or differentiation are often radically shifted by the ways technology does or doesn't "personalize" learning, for whom, and under what conditions.

Within education, there is a long history of conflict between learner-driven learning and externally imposed learning goals, enmeshed with conflict on how research should conceptualize the differences among individuals (whether as a matter of essential characteristics, "prior knowledge," cultural or social histories, etc.). Relatedly, there continues to be conflict over whether educational interventions should promote similarity or dissimilarity among people. In the current moment, much work in the area of educational technology is driven by two framings that could hamper use of technology for learning and thriving.

First, from the research perspective there has been an overemphasis on "what works" when holding learning to an externally defined standard, with far less research focused on what supports learning and thriving as *defined by the learner.* For example, Tseng and Coburn (2019) argued that US-based decision-making focused on the case for whether interventions work according to externally defined learning goals at the exclusion of needs analysis and system analysis. Second, (and this framing is particularly prevalent in the edtech entrepreneurial sector), there is an emphasis on the idea of "personalized learning" *as a way to produce standardized outcomes.* Naïvely, many people see the possibility of using hypertailored learning environments as a way to ensure students learn standardized outcomes, which can have the added effect of stigmatizing those who don't develop standard understandings as narrowly measured. These moves towards personalization bound, rather than expand, the kinds of learning that can take place, mitigating the possibility for responsive and culturally sustaining pedagogies (Ladson Billings, 1995; Paris, 2012) and perpetuating ableism for people with neurological or other noncultural atypicalities (Shew, 2020).

Thus, insofar as individualization in atheoretical hands can be a return to the ineffective, dehumanizing, and disbanded radical behaviorism of the past, there is a deep tension between learning theory and the promises of micro-level personalization. Such technology designs fail along multiple axes: given their antiquated perspective on learning they are unlikely to provide rich learning experiences for students, and for the same reason are unlikely to build new knowledge about learning that speaks to the current state of the learning sciences. Nonetheless, such atheoretical or radical behaviorist technologies can be attractive to venture capitalists and laypeople, who may see in them a simple solution to the multi-scale social problem that is the U.S. education system. Contrasting models of "personalization" are offered by, for example, digital microcredentials and badges, which offer learners greater agency to define and evidence their own learning (e.g., Casilli & Hickey, 2019). In this way, educational technology need not resort to radical behaviorism to support personalization, when the goal of personalization is to expand learners' agency rather than the narrowly defined end of raising their scores on standardized tests.

We can imagine alternative systems in which technology "personalization" is the result of a localized decisionmaking process that incorporates multiple stakeholders including the learners themselves, contrasting with the tendency of technology to assume or enforce homogeneity. For example, constructionist learning environments such as Papert's (1980) LOGO were intended to allow students and teachers to construct their own learning objects based on personal objectives using the full capabilities of general purpose computing, rather than some fixed form of "courseware" that was preordained by a software publisher. Interest-driven learning environments and so-called "passion curricula" that use technology to enable grassroots design and enactment of learning environments (for example, in makerspaces) are more modern instances of this more constructivist or constructionist model of personalized learning (Halverson & Sheridan, 2014; Joseph, 2004; Peppler et al., 2016).

Models of Humanizing (and Dehumanizing) Technologies

While technology can play a role in people's learning and thriving along many dimensions—such as disciplinary and career identity, self-awareness, positive social relationships, critical consciousness, or political engagement—more research is needed on when and how technology promotes or hinders such learning and identity development. Haslam (2006) describes dehumanization as potentially occurring by stripping people of what makes them human and instead treating them as either animals or automatons. Importantly, each of these perspectives has been critiqued recently in educational literature, with Indigenous onto-epistemologies pointing to the falsity in separating humans from nature (e.g., Bang, 2017) and with new materialist and posthuman perspectives pointing to the way materials and objects are inseparable from human activity (e.g., Taylor & Ivinson, 2013). With these critiques in mind, we do not necessarily think about humanizing technologies from a perspective of human exceptionalism. Instead, we here draw on how Yoon et al. (2020) describe humanizing pedagogies:

> Because scholars have used varying terms, definitions, and practices, we define the broader set of frameworks as "the family of humanizing pedagogies" that retain several values, regardless of the label of the pedagogical approach: a) bridging students' lives and identities, community histories, and formal school curriculum by recognizing these structures of power and resisting them by retelling underground narratives that have survived attempts at institutional erasure (e.g., Patel, 2019);

> b) an insistence on the transformation of schooling, therefore imagining futures that subvert or reconfigure what it means to know, learn, and be a knower/learner (e.g., Yoon, 2019b); c) relationships with and respect for students as agents, knowers, and worthy decision-makers about their bodies and their learning (e.g., Camangian, 2015; Dennis, Uttamchandani, Biery, & Blauvelt, 2019); d) explicit focus on healing and righteous anger, justice, and community-building (e.g., Cammarota, 2011; Duncan-Andrade, 2009); and e) abolishing normative ideologies about fixed or single abilities, behaviors, bodies, identities, belonging, and achievement (e.g., Brockenbrough, 2015). These five values, among others, challenge theories of knowing, learning, being, as well as assumptions that time is linear and that past is past. Importantly, humanizing pedagogies are grounded in and practice radical notions of love and hope for marginalized youth and communities—who are typically economically disenfranchised and criminalized based on race, gender identity, and disability, among other axes of power (e.g., Byrne-Jiménez & Yoon, 2019; Ginwright, 2015; hooks, 1994, 2001; Love, 2019; Patel, 2019). (pp. 2175–2176)

From this perspective, for us, humanizing technology is a way to think about how technology can support learning and thriving by disrupting inequity through supporting identity development, self-expression, authorship, collaboration, and activism. In out-of-school contexts, an example is found in the work of the connected learning initiative (e.g., Ito et al., 2013), which has pointed to the way that participation in digital and media cultures can support youth in developing and honing interests, opening up career paths, making and fostering new relationships, and learning about themselves. In disciplinary classroom contexts, *Knowledge Forum* might exemplify a technology that can support knowledge creation and dialogue (Scardamalia & Bereiter, 2014). Indeed, authorship is framed as one of the key aspects of productive disciplinary engagement (Engle & Contant, 2002) and honoring epistemic heterogeneity and openness in such authorship is key to equity-advancing disciplinary dialogue (Agarwal & Sengupta-Irving, 2019). Thus, there are a range of ways that educational technology can support repertoires of humanizing learning experiences within and outside of school.

For contrast, consider a dehumanizing technology, exam proctoring systems. A recent EDUCAUSE report (Grajek, 2020) discusses how much such technologies have been taken up in higher education (and they have also seen use in K-12 contexts; for example, College Board briefly considered such softwares for remote administration of the SAT in Fall 2020, before scrapping the idea; Gross, 2020). To quote Grajek (2020):

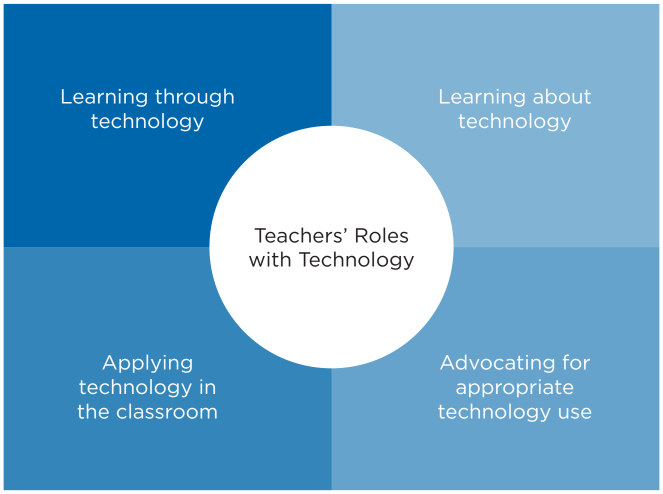
> Online proctoring takes several forms . . . :
> 1. *Passive monitoring of software* on students' computers (by tracking application[s] students are running on their computers and whether they switch to another application while taking an exam)
> 2. *Active restriction of software* on students' computers (by using a "lockdown browser" application that blocks access to other applications during exams or course activities)
> 3. *Passive video surveillance* of students (by using software that accesses a student's webcam to directly monitor them)
> 4. *Active video surveillance* of students (by using a method similar to passive video surveillance software but adding real-time monitoring by live proctors).

We argue that such technologies are dehumanizing, as they are "designed by those who imagine students as cheats or criminals, as deficient or negligent" (Watters, 2020). These link to long histories of other educational approaches that attempt to curtail students' dignity, ranging from "drill and kill" test preparation-centered classrooms to historical inequities around school segregation and forced schooling. Importantly, we see these dignity-robbing approaches more commonly used with poor students, Black students, Indigenous students, students of color, and/or students with disabilities. Such students have been treated by American schooling as broken and the schooling process as one of repair. Thus, technologies such as exam proctoring software are naturally integrated into school ecosystems because they resonate with these assumptions about who children are.

Clearly, technology can support a wide variety of positive processes and outcomes. But it can also be deployed in ways that affront learners' fundamental dignity. More research and design is needed to make sense of how to support humanizing, rather than dehumanizing, uses of technology.

Developing High-quality Educators and Leaders

Building on past research on how educators can use and adapt fast-changing technologies, further research is needed on the ways technology can support educators and leaders as learners, and as professionals and advocates for students' needs.



Educators and Leaders as Learners

Technology transforms what is possible in terms of pre-professional and in-service professional development (PD)for educators, including not only training related to uses of technology, but with regard to their whole professional preparation and development (Fishman & Dede, 2016).

Technology in teacher preparation and development. Technology can be used to advance new conversations among pre-service and in-service teachers about practice. Here, we position teachers as learners and examine the possibilities of technology for their educational development. Illuminating examples exist of technology's possibilities for teacher learning. For instance, in Hotstetter et al.'s (2020) study of a pre-service teacher class, a participatory simulation of the racial wealth gap supported pre-service teachers in having new conversations about social studies education and educational inequity (see also Philip et al., 2016, for an example of data visualizations supporting conversations in educational spaces around racism and inequity). Technology can also support improvements of professional development for in-service teachers. For instance, Sherin and van Es (2009) compellingly demonstrated that long-term participation in a *video club*, in which teachers met monthly to watch and talk about video taken in their classrooms, supported the development of their professional vision. More recently, Kalir and Garcia (2019) have shown how their "marginal syllabus project"—in which in-service teachers, pre-service teachers, and higher education faculty use social annotation to engage with a particular article each month—supported educators' critical literacy and productive discussions about teaching, learning, and equity. Indeed, one need only look at Twitter hashtags such as #NCTE and #Edutwitter to know that teachers frequently use technology to bridge geographic gaps and engage in conversations with like-minded teachers. Thus, we see technology as having lots of possibilities for changing what and how new pedagogical practices are developed and honed by practitioners.

Teacher learning *about* technology in the classroom. While ensuring teachers are able to use technology effectively should be a goal of pre-service and in-service teacher education (Department of Education, 2010), it is not yet obvious what strategies most effectively support such a goal (Bakir, 2016; Kay, 2006). In their study of ISTE-affiliated K-12 technology leaders, Karlin et al. (2018) found that leaders planned technology PD in response to district needs, through a variety of approaches, and evaluated by teacher self-report data. However, they did not tend to conduct formal needs assessments, create sustained or continuous PD opportunities, or conduct more formal evaluations of the efficacy of PD. The notion of technological pedagogical content knowledge (TPCK or TPACK; Mishra & Koehler, 2006) has been taken up by researchers to help characterize educators' competence with regard to technology use. As a construct, however, it has challenges, including a lack of widespread understanding of its meaning and how to best support teachers in developing TPACK (e.g., Harris et al., 2017).

Indeed, as time-constrained professionals, teachers encounter unique challenges in using technology in their profession since technology changes so rapidly and is thus a moving target for professional development and pre-professional training. However, there is consensus that teacher professional development in general should be sustained and reflective (Darling-Hammond et al., 2017). Further, technologies increasingly allow for teachers to get real-time feedback about their own classrooms (e.g., van Leeuwen et al., 2019). It is essential that teachers are supported in using these technologies as part of a classroom ecosystem, rather than only in the context of researcher intervention or professional development days. Moreover, as such technologies proliferate, we argue that they must center students and teachers, rather than policy-makers; to put it another way, they should be learning tools and not institutional compliance tools.

Educators' and Leaders' Roles in Technology Development and Use

Educators' changing roles in school settings are intertwined with their relationships to technology in the classroom and in the larger institutional settings. In K-12 school districts, primary control over making purchasing decisions or specifying technology needs often rests at the district level (e.g., through a district-level technology coordinator). Teachers (and sometimes school leaders) are therefore often treated as technological consumers, rather than authors of technology. Universities may have a more distributed decisionmaking apparatus, and may even have some capacity to customize or author technology, but such institutions nonetheless may mandate the use of standardized learning environments such as centrally supported learning management systems chosen more for administrative than pedagogical rationale.

Generally, teachers are not afforded opportunities to participate significantly in the design and testing of technologies for the classroom, nor are they necessarily trained with the skills and background to create or revise technologies for their own educational purposes. Instead, they select and contextualize technologies, often constrained by institutional policies, and without formal training to do so (Ravitz & Hoadley, 2005). There are two important exceptions. One, teachers use general-purpose desktop publishing and office tools to create and remix multimedia such as PowerPoint presentations or short video clips. Yet, even creating a simple website with interactive features is often either beyond the technical capability of a teacher, or is prevented by school district policies or technology filters. Two, teachers may have a role as technology creators when they are specifically teaching technological "authorship," such as leading a programming class, a robotics club, or some kind of technology media literacy program. In these roles, teachers do have agency in creating and adapting some of the technology they use. Some applications, such as the popular http://web.seesaw.me/ or http://quizlet.com/ support teachers in creating content with low technical barriers to entry, but these tools seldom receive attention in educational research because they support mundane or commonplace activities. Institutional reward structures typically do not necessarily reward technology or content creation, especially in the K-12 system but to some extent in the higher education system

Importantly, tensions abound between differing pedagogical priorities and technological adoption and deployment (Becker & Riel, 2000; Fishman & Pinkard, 2001). Technology can be positioned as "freeing up" a teacher so that the teacher is able to engage in the kind of relational work that only teachers can. Or, it might be doing so to provide the teacher time for curricular or technology design work.

These possibilities are importantly in contrast to a model of educational technology as "replacing" the teacher, common in venture capitalist discussion of educational "disruption." For more generative learning in the age of technology, technology needn't be "teacher proof," but it must be "teacher empowering" (Robinson, 1991).

These possibilities are importantly in contrast to a model of educational technology as "replacing" the teacher, common in venture capitalist discussion of educational "disruption." For more generative learning in the age of technology, technology needn't be "teacher proof," but it must be "teacher empowering" (Robinson, 1991).

This can include collective professional knowledge-building. Teaching standards emphasize the need for educators to systematically reflect on their own practice, collaborate with other professionals to improve school effectiveness, and participate in learning communities of teachers with increasing leadership and contribution to others (National Board for Professional Teaching Standards, 2016), and curriculum materials have been demonstrated to have the potential for serving to support teacher learning (Davis et al., 2017). Technology could similarly serve as a platform for teacher learning and collective professional knowledge-building. For example, engaging teachers in curation, customization, and development of digital tools may serve to build professional knowledge in teacher communities (Ravitz & Hoadley, 2005). Ideally, a mutually reinforcing relationship could exist between technologies developed by teachers and teacher professional development supported by those technologies.

Cultivating Equitable Educational Spaces

For many reasons, technology's potential impact on equity in educational systems—for good, or for ill—is both massive and woefully under-researched. Like other important infrastructure in education, technology is not always designed or deployed equitably.

Equity (and Inequity) in Technology Use: Expanding Access, Conceptualized Expansively

As discussed above, there is a real "digital divide" in terms of what technologies different people and groups have access to (Kewal Ramani et al., 2018). But, as many have pointed out, access to and openness of technologies do not guarantee equitable experiences and outcomes (Reich & Ito, 2017). Consider, for example, the one-laptop-per-child initiative, a proposed solution to (educational) inequality that has proven largely ineffective when other aspects of educational ecosystems are not considered (e.g., Warschauer & Ames, 2010). Underpinning such technocentric solutions is the incorrect assumption that the *root cause* of social inequality is inequitable technological access, ignoring that in the United States inequality based on race, class, gender, religion, national origin, and disability has existed long before widespread computer use.

When systemic inequalities are acknowledged, it becomes obvious that new technologies are likely to be designed and deployed in ways that reify, rather than challenge, these inequalities. Indeed, accessibility is not simply a matter of the presence of some technology (Chandra et al., 2020). It also has to do with how the built-in biases of technologies function differently for different learners. Even if all students have access to the Internet, websites and apps operate differently as they often have racist assumptions built into them that center surveillance and negative messaging of students of color in what Safiya Noble (2018) has referred to as "technological redlining," a term she uses to refer to how racial discrimination is enhanced by the use of technology (see also Benjamin, 2019, on "The New Jim Code"). Furthermore, educational technologies often require a "normative" user and thus fail to offer access to disabled learners, reinscribing ableism in society writ large (Shew, 2020). And many other examples exist for other assumptions built into technology, from disregard for different cultural conventions on people's names, to limiting systems to fixed binary genders, to disregard of our multilingual population.

Any discussion of equitable educational technology access and use necessarily must contend with longstanding racial and cultural oppression at the hands of White supremacy. Without such attention, new technologies are likely to entrench rather than disrupt inequality. Put briefly, we argue that technocentric solutions that disregard the social origins of inequality do not offer significant potential for educational improvement or for impactful educational research, but when considered critically, technology may be a useful tool for educational equity.

Technology for (or Against) Equity: Power, Institutions, Critical Design, and Social Justice

Technology in education plays an important role in cultivating more equitable or inequitable social systems because of the way it mediates the distribution of power among different stakeholder groups, which therefore requires us to critically engage with these issues of power through research and design. Several questions emerge around power in the use of technologies. The first has to do with *whose* reach is extended by the technology. When a technology can expand a learner's engagement in learning, such as through virtual or augmented reality simulations of a scientific phenomenon (e.g., Slotta et al., 2018), it certainly can empower students to take ownership over their own learning, especially when the technology expands rather than constrains the repertoire of choices students can make. As discussed above, technology can also expand a teacher's reach when it allows teachers to offload procedural interactions in a way that frees up the teacher to scale out mentoring relations (discussed in Uttamchandani et al., 2020).

However, it is possible for technology use to constrain, rather than expand, the repertoire of learners' choices. An example can help illustrate. Consider behavior management technology such as ClassDojo, a technology that its website claims is "loved and trusted in 180 countries and 90% of US primary schools" (https://www.classdojo.com/). Briefly, this technology allows teachers to award students points for good behavior, and those points can be traded in by students for various prizes. Of course, there are parts of the ClassDojo technology that could be understood as positive. Teachers have lauded its utility for communicating with parents (Minero, 2017). It allows teachers to monitor behavior changes in an easily trackable way that may support less-biased measures of students. Finally, it is free for teachers. Yet "free" technologies seem to always come at a cost. As Williamson (2017) argues, the behavior tracking features of ClassDojo are psychological surveillance. He argues that the combination of the behavior tracking feature and the communicating with parents feature "positions ClassDojo as a behavioural surveillance platform that extends beyond the classroom to the school leader's office and out to the domestic space of the home" (p. 6). Current knowledge of the school-prison nexus (e.g., Annamma, 2017) and racial bias in technological surveillance programs (e.g., Benjamin, 2019) suggest a strong possibility for such a system to track and punish youth of color in a way that may directly set a school up to justify police intervention later in a student's life.

Importantly, we are not saying that ClassDojo is racist, per se, but rather that in a systematically racist society, and when we know that many actors in educational systems are (with whatever degree of intentionality) racist, technologies can easily become racist in their use. This is something that developers, researchers, and educators must actively design against. Furthermore, technologies are often used for data-driven decision making which can also subject teachers to these same kinds of surveillance by their supervisors, with decisions about hiring and pay attached. When equity is placed at the center, a critical perspective must be taken to the surveilling nature of many educational technologies (Watters, 2020).

How can we take a more just, critical perspective on technology? Important techniques in educational design help answer this question. Older traditions such as participatory design (Ehn, 1988, 2017; diSalvo et al., 2017) or Freire's (1972) methods for increasing critical consciousness through problem posing education have been augmented by newer approaches including: value-sensitive design, an approach that systematically incorporates ethical analysis as part of the design process (Friedman & Kahn, 2000); social design experiments (Gutiérrez, 2008; Gutiérrez & Jurow, 2016) which employ design-based research methods towards "transforming the educational and social circumstances of members of non-dominant communities as a means of promoting social equity and learning" (p. 565); participatory design research (Bang & Vossoughi, 2016) in which collaborative design and research processes wed imagined possible futures, critique of existing power hierarchies, and development of robust new knowledge; or design justice, an approach that centers the role of marginalized communities in challenging structural inequities (Costanza-Chock, 2020).

Although many design approaches may attempt to ameliorate structural inequalities by increasing the participation of marginalized groups, there remain many questions about what types of participation are appropriate or effective, how to distribute the work of participation so as not to unduly burden those who are already marginalized, how to broker among the expertise of designers and other stakeholders, and how these types of values and roles may shift what design processes look like. As these new models of design, or of design and research, unfold, the field is beginning to explore what techniques for coordination and governance can support the necessary implementation of the values around equitable input of various groups.

Innovative Research Methods

Educational research needs to further develop and critique new possibilities for research on education through technology, and research on technology in education. Because technology is both designed and rapidly changing, both foci demand methods for not only understanding the status quo but also techniques for innovation, invention, design, and systems change. Thus, it is worth examining how technology is transforming research methods in their traditional sense of inference, induction, and generalization from data about teaching and learning, but it is also worth examining how technology changes researchers and the research enterprise.

Using Technology for New Data Sources and New Ways of Analyzing Data

Technology brings with it new methodological possibilities—and risks—for instrumenting, analyzing, and representing learning processes and outcomes. Traditionally, data has come from one of two processes: either relatively small amounts of data collected purposefully within the context of a study designed to examine particular questions, or larger amounts of data used for institutional purposes (e.g., grades, enrollment/attendance, etc.) that is then repurposed to ask particular questions. In some cases, these two processes are fused, for example in the case of large standardized tests designed to produce institutionally useful information (like an SAT score for college admissions) while also constructed to be able to study important questions (e.g., whether trends in SAT scores over time are the result of test changes or changes in the measured variables in the population). For decades, the educational research enterprise in the United States has invested in these two types of research. This has been supported by decades of methodological innovation, from item response theory and hierarchical linear modeling, to participatory action research and critical inquiry methods. While work remains to reconcile competing worldviews that underlie many of these methods, education research in general has been an academic area that may more frequently juxtapose these methodological innovations (Hoadley, 2018) in service of "usable knowledge" (Lagemann, 2002; Lindblom, 1979). Nonetheless, education research tends toward clusters of work grounded in particular methods that are shaped by core assumptions and the divide between purposefully collected data in designed studies vs. opportunistically collected data that overlaps institutional, rather than research, goals.

Technological advancements challenge these clusters. For example, take the case of so-called "big data" in education. Big data often refers to the flood of data that can be collected by technology. In our case, all four of the major technology changes conspire to afford new types of educational data that are more intimate than ever before. Not only does the ""total data" technology trend allow us to amass, store, and process many more datapoints about learners than ever before, the immersiveness of retina-grade experiences means that we can collect fine-grained interactional data, and the increasing ubiquity of technology means that this data is collected from more individuals in more contexts. AI and other advanced technologies then allow processing of this data. For instance, in the predigital age, the difficulty of sensemaking with data limited how we could do research as much as the availability of the data itself; for example, the challenge of the *Oxford English Dictionary* in maintaining accurate etymological data involved monumental human effort, mediated by small index cards or "slips" on which quotations were recorded (Simpson, 2016).

Now, not only are clerical but analytical tasks automated, which allows even rich non-numerical data to be subjected to algorithmic analysis. These techniques include not only advanced inferential statistics, whose properties are relatively well understood by education researchers, but also techniques such as machine learning and connectionist computational networks, which produce results that may have hard-to-examine flaws (Rudin, 2019). Beyond big data, technology impacts numerous aspects of educational research. For example, technologies such as brain imaging, eyetracking, or personal fitness trackers have allowed collection of neural and physiological data that was previously inaccessible. Audio and video recording technologies have had a profound impact on fieldwork. Online search and collaboration tools have transformed the information management and knowledge building tasks educational researchers undertake. Justifiably, many are excited by how technology may advance research methods and the practice of research.

In education, adoption of new technology-enabled research methods yields both significant opportunity and risk. To begin, we have ethical and societal questions about what data we should collect, and what we should do with it. Questions around ownership and consent of "public data"—such as YouTube videos that youth may post on the Internet—have intensified with the increasing ease by which such data may be curated and culled for research purposes through technology. In a striking recent example, Black academics took to Twitter with the hashtag #BlackInTheIvory to share their experiences of racism in academia. Several days later, a tweet (to our knowledge, now deleted) offered to share the #BlackInTheIvory tweets, as downloaded through a web-scraping tool, to anybody who wanted to use them for research purposes. However, #BlackInTheIvory co-founders explicitly noted that they prefer for these stories to not be used, especially by non-Black people, for research purposes. Co-founder Joy Melody wrote in a tweet, "Also, to the folx gathering tweets for 'research' or to 'learn' / I get it, we cannot legit stop you. It's the internet. It's twitter. But #BlackInTheIvory really wasn't created with research in mind." (Melody, 2020). As this example shows, something being publicly accessible or available is not an ethical license to use it as a "big dataset," even if technology makes doing so increasingly possible.

Secondly, in focusing more on methodology, we need to concern ourselves with how research differs in the context of technological advancement. For instance, Daniel (2019) highlights several important differences in the properties of educational data mining and learning analytics research versus the properties of educational research more generally. These include some obvious differences such as how big data research might use precollected data and the context in which that data was collected might be unknown to researchers. And, educational research in designed studies typically has a focused epistemology and ontology, where in big data research these might be more emergent. But Daniel also points out some less obvious differences; for example, big data research might allow realtime analysis which can subtly shift the relationship between the researcher, the participants, and the inferencing process. And, in systems where different computational regimes are collecting and analyzing data, and that data is then aggregated or contrasted, inferences can be even more murky. On the other hand, there is significant opportunity for using technology to enhance research methods, not only through clerical or analytic ease, but also in terms of epistemological questions. Shaffer (2017) has described an approach to "quantitative ethnography" in which the inference frames of ethnography are used with quantitative tools by changing how sampling, segmentation, modeling, and saturation are conceptualized. Drawing on ethnomethodology's challenges in using impossibly rich data, he attempts to consider how technological tools can be used to examine impossibly vast quantitative data.

In traditional and critical qualitative research, the use of computer-assisted qualitative data analysis (CAQDAS) programs and other digital tools have created new possibilities not only for data collection, transcription, and analysis, but also for new ways of thinking about validity and trustworthiness of analysis (e.g., Paulus & Lester, 2021). We can even begin to consider, through technology mediation, what *distributed* research looks like; while many social science researchers use platforms like Amazon's Mechanical Turk (and many computer scientists use platforms like visual Captchas) to issue microwork to people as research subjects, scholars are beginning to use technology platforms to engage people as research analysts (e.g., the Galaxy Zoo project which enlisted the public to analyze astronomical images [Lintott et al., 2008], or the FoldIt online game, in which the collectivity of social gameplay was able to make novel scientific discoveries about protein folding [Khatib et al., 2011]). While participatory forms of research are not new, the ways in which scientific thinking (ranging from question posing, to data collection and analysis, to inference) can be distributed across sociotechnical systems offers new possibilities for education researchers.

One rapid metamorphosis related to technology and educational research is related to how we maintain research ethics. We have already mentioned how technology in pedagogical use in education runs up against historical and systemic inequalities and can reinforce them; this is doubly true if dual use of these technologies for research use helps justify otherwise untenable arguments for eroding privacy. A second issue is the way in which technology can lend a sense of legitimacy to research results that are otherwise ethically or intellectually flawed. For example, the U.S. government under then-President Trump proposed rules that would shield banks from liability for racist 'redlining' practices if those practices were the result of technology-mediated algorithms and data (Donovan, 2020; Glantz & Martinez, 2019). In educational research, technology-mediated results can be inappropriately promoted if the technology either obscures problems with the data and analysis, or if the high-tech apparatus used adds unwarranted legitimacy through a sense of being more "advanced," "objective," or "scientific."

Methods for Studying Technology in the Educational Sphere

Because researching technology in education is at some level the study of what is possible and not just what exists, new methodologies are being developed to better look at the impact and potential of technology for learning, including important ways of blending research and design. The traditional model of studying technology in the educational sphere often derives from extending research on theories of learning to theories of instruction (Bruner, 1966) in which a positivistic hypothesis of "does [intervention] under [circumstances] improve [outcome]" is tested. This framing by necessity separates the creation of interventions (e.g., technologies) from their evaluation. It is of course sensitive to useful or unhelpful framings of the concepts intervention, circumstances, and outcomes. The design-and-evaluation approach thus also depends on invention of interventions to study. Unlike engineering, in which known processes can construct solutions to well-specified problems with roughly predictable outcomes, design engages problem-solving in ill-specified problem areas, and often must deal with unpredictable outcomes. For this reason, educational design, and especially educational technology design, includes both problem definition aspects (which may be connected to empirical investigation through needs analysis or other means), and exploratory iterative refinement of designs based on implementation data, which helps ensure the design has the desired impacts in practice.

However, this rather reductionist schism between invention and evaluation has led the field to frequently ignore not only the context sensitivity of designs and the differential impact on students with individual differences, but also two meta-issues: the difficulties of separating what must be done to learn from the design process, and the difficulties of separating what must be done to learn from the research and evaluation processes. As Herb Simon (1969) noted, "The contingency of artificial phenomena has always created doubts as to whether they fall properly within the compass of science. Sometimes these doubts are directed at the . . . difficulty of disentangling prescription from description. This seems to me not to be the real difficulty. The genuine problem is to show how empirical propositions can be made at all about systems that, given different circumstances, might be quite other than they are" (x). In the most simple terms, research on "What works?" does not answer the question of "What could work?" or "When would this work?" or "What works where?"

Methods for studying technology therefore have taken three turns related to compensating for these omissions: widening the gaze, imagining possibilities, and embracing change. Each of these modalities may challenge what we define as research, but each is essential to create what Lagemann (2002) called "usable knowledge." In widening the gaze, methods have been introduced to explore the relationality and contingency of how technology and learning influence each other, ranging from uses of systems science to critical inquiry. In many cases, this has entailed embracing more humanistic, descriptive, or explanatory forms of research and less prediction-oriented ones. In imagining possibilities, methods (often drawn from the fields of futurism and design, but also techniques such as Freirian critical consciousness-raising) to uncover and understand current conditions, and to imagine as-yet unrealized possibilities. In embracing change, the researchers' stance with respect to monoliths such as "adoption" or "spread-and-scale" changes, and the researcher incorporates not just findings but implications and actions into the research agenda. This might take the form of more participatory or liberatory research methods, or it might focus on yoking research to practice in various ways, from research-practice partnerships to change laboratories.

Additionally, some of the methodologies have a longish history, such as Participatory Action Research (Cammarota & Fine, 2010), while others are newer, such as Design-Based Implementation Research (Penuel et al., 2011). In this general area, we view design-based research methods as a somewhat central touchpoint, with a core tenet of linking the design and research goals through flexibly shifting from goals of generalization to particularization, or in other words from finding useful generalized abstract knowledge but also attempting to create useful particular implementations in real contexts (Kali & Hoadley, 2020). In general, these activities still fulfill the principles of scientific research in education as described by Shavelson et al. (NRC, 2003), including posing significant questions that can be investigated empirically, linking research to relevant theory, using methods to permit direct investigation of the question, providing a coherent and explicit chain of reasoning, and disclosing research in a way that encourages professional scrutiny and critique. Where these methods differ from the NRC principles is in not depending on reproducibility and replication, which many qualitative research traditions explicitly decry as epistemologically impossible for questions that depend on the uniqueness of human histories, cultures, and interpretations of experience.

Where Do We Go from Here?

In sum, we have examined the ways technology is producing sea changes in human society, key tensions regarding how those changes will affect education, and recommendations for areas of further investigation. In the sections below, we examine how to support such investigation, including not only more traditional positivistic or quasi-positivistic research, but also critical and design approaches that can help shape future educational systems. In particular, we discuss the role of technology-centered R&D in shaping the future of education, the funding landscape for such R&D, and how current national and global crises impact this role.

The Role of Research and Development in Shaping the Future of Education

Research and development, including critical and design-based approaches, are critical in shaping how education is transformed by technology from this point forward. As discussed in the sections above, we see the traditional role of education research—to inform, predict, and explain how educational systems impact learning—as being multiplied by the need for design and improvement of systems. Research should connect to our whole range of ways of knowing not only what is happening or how things work in schools, but also what might be possible. Technology, as a particularly rapid moving target in educational research, has highlighted the limitations of a narrow version of research. Historically, we have had a loose coupling between on the one hand, research that is focused on building and testing predictive theories, and on the other hand, design that is focused on building and testing actual interventions. If we center the systems of education rather than the researchers, we see that despite calls for "data-driven decisionmaking," "continuous improvement," or the more generic "reform," *most components of the educational system, from policymakers to individual educators, have very limited effective access to research capacity.* The rise of research-practice partnerships has many drivers, but probably the most significant hallmark of how such partnerships are discussed is that the research aims and questions are driven in part by those who would need to apply the research to practice.

For contrast, consider other sectors where research and practice meet. In healthcare, although the individual practitioner or even large healthcare systems may not have large research capacity, whether for drug development or epidemiological research, there are a number of systems in place to try to make sure the research and design connect, ranging from institutions whose sole purpose is to do translational research, to teaching and research hospitals that help research-centric faculty maintain a connection to clinical practice. Drug companies also attempt to bridge R&D and practice, both through uptake of pure research and through marketing to and training for practitioners. In the agriculture sector, the United States has had a model that, through a series of public funding decisions, helped establish the land grant college system, and crucially, the agricultural extension services which housed professionals who would help drive not only dissemination of agricultural research findings, but also ensure that such research was responsive to the needs of practitioners, i.e., farmers, at the level of every county in the United States (Rogers, 1988). In this way, the agricultural extension model represents an important example of bidirectional knowledge transfer to and from the research community.

The ecosystems for research and innovation in each of these cases have different funding models and different splits between public and private entities, but in both cases there are specific ways in which practitioners have access to research capacity. Within the US, the closest in the education sector would be something like the Regional Education Lab system, which performs activities focused on research translation, similar to some institutions in healthcare. However, perhaps especially because of the politicization of educational systems, the levels of funding necessary for not only studying but inventing commercially viable learning technologies (typically a high-cost activity) has been solely available to commercial publishers and technology companies. This in turn leads to several weaknesses; without rigorous hurdles like FDA approval, these companies need not study the efficacy of their products. With only commercial incentives, such companies have no incentive to innovate if their profit and market share is secure, and have disincentives to examine critically the negative effects of technology.

Partly due to the state-federal division of labor in U.S. education, government efforts have been divided as well, with federal funding going to prototypes or lab-based innovation, and state funding going to easily deployable solutions, usually from commercial providers rather than academic labs. And, the timescales of commercial and academic work help ensure that academia can't keep up with the for-profit sector, either in the design of new innovations for release, or even in evaluating and studying what they produce. This is particularly important when considering technology in education because design quality and methodological alignment of research both hinge on (a) tight feedback loops between the creation of interventions and the data on those interventions, and (b) the current division of labor between the education research sector and the technology industry (to say nothing of intellectual property or economic incentives) nearly precludes such tight feedback. Alternatives are possible; while not able to achieve all its aims, Brazil's governmental effort to move the country to using and developing free and open source software shows that distributed efforts across sectors can lead to scalable, sustainable software development and use (Oram, 2016; Shaw, 2011).

What is needed are ways for pure research to better connect to applied research and development, and on to what is often called "dissemination" although is more appropriately thought of as systemic transformation of systems for educational practice. Since the researchers are the fewest in number among the different categories of stakeholders, it is important that researchers relevant to educational technology R&D have the ability to connect with as many other stakeholders as possible, including not only front-line educators, but also designers, publishers, policymakers, and the public, and that their work is as relevant as possible to those audiences. To use a chemistry analogy, if the researchers are the limiting reagent in the chemical reaction of innovation, we need to increase the ability of the researchers to react with the other ingredients, and to ensure that there are enough researchers working in this particular test tube to keep the reaction going.

Current Funding-Related Challenges for Education and Technology R&D

Effective support for impactful R&D in this area faces several key challenges. Current work overemphasizes design and development without research-based insights, and overemphasizes either theoretical but hard-to-apply research, or test-and-disseminate, evaluation-focused research. These modes of inquiry often disregard expansive notions of human thriving and the professionalism of educators and educational leaders, and entrench inequities. There is an opportunity to complement and shift our educational technology landscape to incorporate more humanistic, socially just, and critical approaches to educational technology R&D. We predict that if funders take up a central role in defining education research as it applies to technology in education systems, that it will shift the ways in which investments are allocated and would increase our capacity to invent, deploy, and understand technological systems that support the goals of more equitable human development. Failure to significantly shift these investments will likely lead to exploitative technologies that exacerbate inequity and dehumanization, and entrench problematic systems.

The "D" in R&D Requires Different Ways of Thinking About Funding

Design and development are expensive (especially technology design and development), and require different models of funding than social science research generally. In education, we see this tension playing out as a disconnect between educational researchers often with relatively low budgets related to topics highly relevant to theory but minimal capacity to design and develop, or computer science researchers, founders, and the corporate sector with large budgets that can cover design and development, but which are not driven by either learning theory or sophisticated empirical education research. In these circumstances, the insights which could lead to critical improvements of designs and systems come long after those systems are built, deployed, and entrenched (e.g., the research on learning with social media often lags years behind the development of social media platforms and features). In other areas of design-oriented research, such as the early development of computing technology by the U.S. military (Fuchs, 2009), the space race of the 1950s and 1960s (Goldston, 2008), or even global responses to the current COVID-19 pandemic, large amounts of funding were marshalled around common goals. But this funding has been at a mix of timescales, and with a strong resistance to centralized, insourced models for research and design, if not development and implementation.

The Department of Defense's Advanced Research Projects Agency (ARPA, formerly DARPA), which is credited with funding the precursors of everything from lasers to the Internet, operates by both constantly scanning the research horizon for potentially applicable research and by funding a mix of basic science and applied engineering research to develop early-stage prototypes. Funding to take promising prototypes to market is likely due to the flush budgets for military procurement. The Obama administration repeatedly proposed an ARPA for Education to Congress (Shilling, 2015; Winning the Education Future, 2011), but this was not taken up. How such a funding source would blend research and development, and mix field-initiated research with global or international priorities and goals, is unknown, but if an ARPA for Education were constituted similarly to the existing Defense Department agency, it would mean a heavy reliance on the nimbleness—but also open-mindedness and future-mindedness—of program officers making decisions. (Of course, this model is not perfect, in so far as militaristic goals for education are often at odds with equity approaches; see for example Vossoughi & Vakil, 2018). Such a model is in contrast to the peer review models held by the U.S. National Science Foundation, which mixes program officer discretion with peer review, or that of the U.S. Department of Education, which relies solely on reviewers and not staff judgments for funding decisions, and it is unknown whether the DARPA mechanisms would have advantages over the NSF or Department of Education models that use input from the field differently.

Kali and Hoadley (2020) describe the problem of design-linked research as a continuum between generating abstract knowledge and particularization of that knowledge to applied circumstances, or more succinctly, as a tradeoff between the "true" and the "actual." This continuum implies that a range of activities, from engineering to science, are needed to make progress in wicked problems like educational change. However, the funding systems that closely link these two are often ill-suited to the continuum, unnecessarily decoupling design and research. Future funding will need to ensure that research relies on the best available work in both computer science and in other disciplines in the learning sciences. We will need to make investments in a variety of levels of innovation, from the relatively sure bets that are well understood, to the highly future-oriented and novel designs that could contribute entirely new genres of learning technologies in the more distant future.

And, the research will need to include ways of designing for scale, disseminability, maintainability, and reliability, similar to software engineering methods used for high-stakes applications in other sectors.

Conclusions and Next Steps

The opportunities and threats of technology's rise in the context of education do not preordain the outcomes. We can reasonably assume that things will go badly if people equate more technology with better education, or if we leave the development of that technology up to institutions that have naive views on learning, a misplaced faith that anything "disruptive" is good, or ulterior motives such as profit or creating a compliant populace. Perhaps more subtly, we can reasonably assert that even with our best currently available designs aimed towards the most prevalent models of design, evaluation, and implementation that we would fall short of our aims. Our current practices overemphasize cognitive outcomes to the detriment of sociocultural and sociopolitical ones, without regard to important aspects of human thriving, and overemphasize—through randomized clinical trials or other population-centric methods—looking at average population-level effects rather than impacts on individuals. These biases have a high likelihood of exacerbating social injustice and inequitable educational systems through our technology interventions. What, then, are the alternatives?

Key Problems between Technology and Education

Key problems	• Establishing what we want from our educational systems and technology • Understanding how to create systems that reach those aims
Key challenges in addressing the problems	• Educational systems are inherently more complex than our scientific models • Even with good science and good design, we can not achieve solutions if the aims are unclear
Imperatives for progress	• Commit to prosocial values and equity • Develop new, integrative methods for research and design • Create new relationships and structures to support R&D and enactment
Mechanisms to support imperatives	• Accountability of R&D to shared values • Incentives to consider future, as well as current, possibilities • Transparency and inclusive, respectful dialogue

Ultimately, we have two relevant societal problems: deciding what kind of educational outcomes (broadly conceived) we want, and then working to achieve them. Connected to the latter is better understanding how our actions and choices influence the outcomes we desire. Rittel and Webber (1973) note that some problems are inherently "wicked" problems, i.e., they are not amenable to a predictable solution through the application of science and engineering methods. Yet, at the beginning of the twenty-first century, we have more empirical data on and better theories of how people learn than ever before in the history of the human race. This research is not irrelevant, but rather incomplete. The goal of trying to study and engineer solutions for human systems meets two inherent challenges. First, people are messy; we must resign ourselves to incomplete science since the breadth of human experience is ever changing, and broader than our ability to reduce it to scientific laws. Even when we develop such scientific findings that generalize to an extent, we are limited by incomplete knowledge of the initial conditions—our models will never be complex enough to plug in "culture" or "past personal history of experiences" as tidy covariates. Secondly, as noted by Flyvbjerg (2001), science cannot substitute for people choosing values. This is particularly relevant in educational research because no amount of science about how people learn will address conflicts that society has about what we want our educational system to accomplish: conflicts that are sometimes acknowledged, but frequently obscured.

For example, the conflict between a parent wanting to give a child the best possible education to get ahead in the world may inherently conflict with the goal of having an educational system that reduces inequalities between learners. Technology in education often provides a smoke screen for simmering conflicts about these goals that underlie the decisions we make in building new tools for teaching and learning. Those who shape technology's development and deployment embed their assumptions about means and ends of education into their tools, often with far less public scrutiny or debate than, say, a curriculum or textbook adoption. Technologists often claim a high ground from which they alone can see the future on the horizon, but frequently suffer from lack of a breadth of perspective outside their own experiences. Researchers in technology domains often overlook or belittle the expertise and knowledge base of social scientists. Within social sciences, those who pursue and study equity are in turn often marginalized. Likewise, practitioners and parents confront twin challenges: either their perspectives are overlooked as not "expert," or they are overgeneralized outside the realm of the experiences they represent. Without honest respect for the value of each community and a willingness to engage inclusively over the problems of education, we will never apply the insights we need. Developing such dialogue will require significant effort, on the part of all stakeholders, to increase our technological literacy, collective understanding of learning theory, and shared conceptualizations around social justice praxis. Learners, teachers, parents and families, researchers, designers, and policymakers need enough common language to work together, or at least to make conflict visible and mutually understandable, and need to attend to power dynamics in their conversations.

The imperatives related to the current situation are daunting, but relatively clear. First, we need to commit to just, prosocial, thriving-oriented values, which will necessarily entail costs that society has so far been unwilling to pay (especially in the United States). Second, we will need to create new methodologies for not only research but also design that integrate these values into a far more multidisciplinary, holistic, and systems-oriented epistemology. On the design side in particular, this will require a fostering of civic imagination unlike what the United States has experienced in living memory. Third, we will need to create new institutional relationships and structures that properly integrate research into other sectors so that "throw-it-over-the-wall" research becomes the least common model, rather than most. Among these new relationships and structures, the most difficult will likely be the public sector implications of linking research to publicly funded education; this will entail significant policy evolution to reclaim aspects of public education as public goods, and significant resource redistribution based on best available research and a fundamental value for human thriving, rather than solely political stances. Challenging though these imperatives seem, they are far less challenging than the likely conflicts and costs to human dignity likely if we continue to assume that our prior assumptions about research, learning, and technology are true.

At least three mechanisms will need to be developed to meet these imperatives. We need to develop accountability systems for both research and for technology designs that ensure that equitable impact is a central criterion for success rather than an afterthought. For instance, one might envision something akin to an environmental impact review, an equity impact review, that could preclude thoughtless implementation of equity-eroding interventions. We need to incentivize both systems of education and systems of research to consider tomorrow's opportunities and problems alongside today's opportunities and problems. And we need models for transparency and collaboration that allow the professions of policy, research, design, and education to support each other rather than maintaining silos of expertise. These mechanisms will all entail a mixture of top-down and bottom-up coordination, and some ceding of turf from technologists, educationists (both researchers and educational practitioners), and learners themselves.

If we imagine a future in which interlocking systems of design, research, and educational practice can systematically work together to iterate not only our technologies, but also the educational systems they are intertwined with, we can foresee a future in which learning and knowledge are democratized and in which human thriving can be centered. Such a system should be able to not only improve over time with respect to stable conditions or aims, but also has the potential to anticipate and adapt to changing conditions and aims, and to a changing technological environment. Failure to imagine and work towards this future, however, is likely to produce a technological dystopia in which control and subjugation, rather than thriving, are the predictable outcomes. The choice is ours.

Urgency of the Need for Research: COVID-19, the Black Lives Matter Movement, and the Realities of Educational Precarity (September, 2020)

Notably, this report was completed during the COVID-19 pandemic, a time period in which the ways technology have and have not failed us in education are increasingly visible, and in which the need for thoughtful, critical, and actionable research on education and technology is urgent. Further, the Black Lives Matter movement, through years of diligent and radical work, and in the wake of several high-profile police murders of Black people, has received new or renewed attention and validation from non-Black people and from private and nonprofit entities. Together, these related phenomena have laid bare the way technologies have, and have not, failed "us" in education, and for whom. It also has laid bare the necessity of investigating technology *only* with an equity lens; never without.

Right now, certain things feel more visible to more people now than ever before, at the intersection of learning, technology, and current events. For example, here are just a handful of social phenomena related to technology and social life we watched unfold as we wrote this report:

- **Participating in "remote instruction" reproduces inequity.** As COVID-19 caused schools to rapidly shift instruction to distance modalities, factors such as parent presence, access to broadband, and access to disability accommodations had an even greater impact on students' learning (see Cohen, 2020).

- **Technologies can support human flourishing, but they can also exacerbate oppressive extremism**. One need only look at the role of Facebook in spreading "fake news" about social justice efforts, or the role of the Youtube algorithm in funneling users towards White supremacist content (see Roose, 2019).

- **Military technology is used by schools to brutalize.** Police brutality, targeting people of color and particularly Black people, is not a new social phenomenon, but it has received increased attention from (White) people in recent months. This increased scrutiny has made apparent just how tight the connections between policing and "school security" are (see Ceasar, 2014).

- **Privacy has been curtailed.** In the rapid move online, major technological companies have treated student privacy, and FERPA requirements, in problematic ways, often dodging liability for predictable lapses in security when private data is aggregated, processed, and stored (see Zhou, 2020).

- **Accommodations (e.g., working from home) previously described as impossible are now widely accepted,** pointing to how social, political will—rather than plausibility, necessity, or ethics—has been the key factor for employers in deciding whether to create accessible workplaces (see Campoamor, 2020).

- **Globalization has complicated the ethics of commercial technology availability.** Apps built and deployed outside of the United States are treated suspiciously by the U.S. government (see Disis & Hansler, 2020). At the same time, U.S.-based companies have removed apps from their stores that support the democratic uprising in Hong Kong (see Nicas, 2019). These instances show windows into how government interests hugely influence the distribution of technology power.

These are sociotechnical issues that of course centrally affect learning and education. Research and reflection is urgently needed to ameliorate these horrors. In a moving recent essay, Arundhati Roy (2020) analyzes how the ruling Bharatiya Janata Party, a right-wing Hindu nationalist party, has handled the pandemic in ways that only exacerbate caste and class inequality in India. Situated in this context, she concludes, “Historically, pandemics have forced humans to break with the past and imagine their world anew. This one is no different. It is a portal, a gateway between one world and the next.” We similarly see the possibilities of this moment, in its tense surfacing of things many already knew but some did not, as a time to reflect and imagine brighter alternatives.

A Coda from Chris

September 2020

The circumstances under which this report is coming together seemed unimaginable just a few months ago. On the one hand, even with the worldwide acceleration of populist autocracy and with inequities in society in stark relief throughout 2019, it generally seemed that educational research had a fairly well defined role to play in addressing these challenges, and that it had a lane to stay in that could map onto some of the overarching areas Spencer identified in its self-study and field scan. On the other hand, urgency has been thoroughly displaced by emergency, not only in the city of New York where I live, but globally. “Intersectionality” risks becoming an overused concept, but we can’t disentangle the pandemic, the exploding crisis of police (and school) brutality and racism, and perhaps most chillingly the stark demonstration of leaders globally that they simply do not care if people live or die, but only that the concentration of wealth and power accrues to them. In an instant, the U.S. Congress redistributed trillions in wealth, just as in an instant nearly 1 in 5 Americans became unemployed, and remain so, while hundreds of thousands of people die. I grieve colleagues and friends who died without funerals, and attempt to enact care in my online classrooms and research meetings, while seeing stunning courage and stunning cowardice from colleagues in similar situations (“Let’s use the pandemic to recruit subjects for our unrelated research study!” “We’ll handle racism in our unit by asking for more scholarship money and put the lone person of color in charge of doing the work!”). Nearly every one of our writing meetings, Suraj and I would shovel tweets to each other of vital, newsworthy developments about power, money, education, and technology that had relevance for this document, while scratching our heads on how to prioritize which part of the manuscript might now deserve yet another rewrite. We abandon trying to keep up as midyear arrives, knowing full well that the world will likely be again significantly remade in the time between now and January 2021, by which time the United States may or may not have had a fair election, which will profoundly impact both global balances of power, and very local balances of power.

One of the most novel and surreal aspects of this time for me are the demands for transformation. When I began working on this manuscript, I was entering into a time of personal crises, from which I emerged just as the world was entering into a time of global crises. I have clung to a thought from the artist and podcaster Kirya Traber, who said “I’m grateful for the growth that I’ve had before this moment, so that I feel stable and grounded enough to take this and all of the discomforts, and invite learning and growth from them” (Traber & Smith, 2020). I am personally unsure that I’m stable and grounded enough—and am unsure that academia is stable and grounded enough—to do this. Yet it does make clear the triple challenge we face: of digesting our past traumas and injustices and treating them as our strengths, of building towards a future of continued learning and growth, and of being uncomfortable in the present moment while remaining stable and grounded—while taking care of ourselves and each other in the here and now. For me, that includes overhauling my own research agenda and positionality as an academic, ferreting out my own internalized racism (and misogyny, and ableism, and homophobia . . .), filling in the gaps in my own education in political science, economics, history, and so on; in short, trying to figure out what it means to live my values in a world I barely recognize.

And yet, I remain convinced of a central point: the inflections of technology and education and their intersection will enormously influence the future we arrive at. I’m not just speaking of classes driven online by COVID-19, but more vitally of the ways in which technology provides points of power and control that could significantly alter what children and adults know. If our goal is social justice, human flourishing, and/or even survival of the species in the face of epochal climate change, at the minimum we will need to ensure that information and learning are free enough to save truth, which centers the question of how our technologies are used in learning.

A Coda from Suraj

September 2020

As I write in this historical moment, I am trying to think about responses to COVID-19, racism, and justice from more global perspectives. I am of course reviled by the kinds of atrocities that are unceasingly perpetuated on Black, Latinx, and Indigenous people, on LGBTQ+ people, on youth, and on the elderly. I am also increasingly horrified by what I see done “in our name,” ostensibly for our protection. Looking across pandemic responses, I am struck thinking about if indeed countries that are seen as more authoritarian than the United States really are best understood on these terms, as I consider how much blood is on the hands of the United States empire.

I also write from a place of personal precarity. I am thinking not only about what educational research gets done, but also by whom. I defended my dissertation in the learning sciences in early March 2020, just before official shutdowns and quarantines began in Indiana and elsewhere. I found myself adrift in the academic job market, faced with the added considerations around what kinds of movement were possible, to where, and at what pay. A general air of “if one really want to be a researcher, one must be willing to sacrifice” pervades the discourse in many ways. You may be asked to live in a place where you could not realistically find a romantic partner. You may be asked to work for relatively low wages for so-called “knowledge work.” You may be asked to surrender your ethics and artificially homogenize your communities for journals’ consumption. Understanding these dimensions—exploring who researchers are—is essential to understanding what will be researched in the future.

Living alone since the lockdowns, technology has been a salve. It is the only way I have been able to stay in touch with family, and the digitization of some things, like board games, have allowed for a lesser but recognizable pandemic substitute for intimacy. For that I have gratitude, even as I generally remain skeptical of technology’s role in catalyzing equitable social change.

And yet, maybe I’m just not dreaming big enough. Sadiya Hartman said, “So much of the work of oppression is about policing the imagination.” And so I come back to radicalism. As Angela Davis has said, “Radical simply means ‘grasping things by the root.’” Historical roots & imagined branches, together, I hope offer a way forward.

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Appendix: Sample Questions to Consider in Future Educational Technology Research

Future research in the area of data ethics, education, and technology might seek to answer questions like:

- How are privacy rights currently implemented by educational institutions, corporations, and the law? What power structures are embedded in these implementations?
- What are alternatives to the "terms and conditions" model for how learners assent to giving off a data trace? How does data autonomy influence learning and thriving?
- What is the psychology of privacy in education both for learners and parents or educators? Can we map out the knowledge gaps that could be closed to allow for truly informed consent around uses of educational data?
- What are the impacts of surveillance, privacy, and different models of data control on learning and thriving (including self-quantification)? When does data support or thwart learning and thriving?

Future research in the area of "personalization," education, and technology might seek to answer questions like:

- How does technology systematically entrench or destabilize standardization of what counts as learning? Where does technology favor homogeneity vs. difference among learners?
- How can we evaluate technological interventions in the face of varying learners (e.g., design frameworks such as universal design for learning) and varying learning goals (e.g., different models of civic engagement)?
- What infrastructure is needed for technologies to be adapted to or created for local needs or the needs of individual learners? Are there infrastructures needed to decentralize decision making about educational resources?

Future research in the area of humanizing pedagogies and technology might seek to answer questions such as:

- **What** kind of developments are supported by everyday technology use (e.g., disciplinary and career identity, self-awareness, positive social relationships, critical consciousness, or political engagement)?
- What are ways in which technologies support processes that inhibit development or dehumanize learners?
- **Which** technologies support these developments, and where (in school/out of school)?
- Finally, **how** does technology support this development?

Future research in the area of technology's role in supporting teachers learning might seek to answer questions such as:

- How can technology support teachers as lifelong learners in their disciplines, as pedagogues, and as technology users in an ever changing knowledge-intensive environment?
- How can we build on prior models of what it means for teachers to effectively leverage technology in their teaching practices (e.g., extending TPACK) to include new learning goals, new technologies, and new models of knowledge?
- How can we address the challenges (pedagogical, financial, regulatory, and infrastructural) of training teachers to use technology given the rapidly changing technology environment?

Future research in the area of teachers' roles in educational technology development and uptake might seek to answer questions such as:

- How can we support teacher technological authorship by making technology with teachers?
- What kinds of technologies do teachers currently feel are empowering, rather than what researchers feel should empower them?
- How do educational systems constrain or afford use of technology by education professionals (including cost-benefit analysis, processes of system selection and procurement, regulations or IT administrative policies or restrictions, organizational cultures, etc.)?
- What is the role of technology as it relates explicitly to teacher professionalization and implicitly to teachers' working conditions?
- How and when is technology supportive of educators and educational leaders to coordinate and advocate on behalf of learners, and in what ways is technology being used to diminish the ability of education professionals to influence decision making in education?
- When and how does technology help align or cause opposition between teachers and students?

Future research in the area of expanding access conceptualized expansively might seek to answer questions such as:

- What forms of digital divides exist, moving beyond "who has technology," to who has access to what technologies, when and under what circumstances, and how does this inaccessibility curtail or constrain opportunities for learning?
- How does technology in education differentially impact learners not only based on wealth or class, and not only based on variance in demographic characteristics such as race, gender, or ethnicity, but also based on the wide range of human cognitive, physical, and perceptual abilities (whether pathologized as "disabilities" or not)?
- In what ways do differences in access to technology obscure other important metrics such as access to training, accessibility of the technology to different learners, or different cultural and contextual barriers to technology use (e.g., gender stereotypes, language differences, the need for a safe place in which to use the technology, etc.)?

Future research in the area of technology for equity might seek to answer questions such as:

- Can we advance alternative forms of design, such as participatory design, value sensitive design, or decolonizing design methods that can be used to produce more equitable technologies?
- How can we deeply theorize and critique technology use in the school-prison nexus and disparate uses of technologies for compliance and control?
- Are there opportunities for technology design to address systemic or institutional injustice, or ways in which technology is already used as a form of resistance to injustice?

Future research in the area of technology for research methods might seek to answer questions such as:

- How can we incorporate issues of justice and equity into technology-enabled research, moving beyond thinking about "race as a variable" (or gender, ethnicity, ability, etc.)?
- Can we maximize benefits and minimize risks in using new technology-enabled datasets including "big data" research (learning analytics and educational data mining), as well as new forms of data such as facial recognition, biometric data, algorithmically identified information in databases, speech recognition etc.?
- How should consent should work when collecting or analyzing these data sources?
- What are ethical frameworks for research in educational settings that consider not only risk/benefit to individual subjects (as with IRB review) but also consider consequential validity of findings and potential implications for technology design and development?
- How can we ensure ethics, dignity, and safety for researchers and participants around "public" data, rights, and consent?
- How does technology change qualitative or interpretivist research in education, with special attention to how these forms advance or complicate accepted existing approaches?
- What are the limits of how technology-derived data can be meaningfully used in educational research (e.g., studying what types of inferences are appropriate to make from fMRI data, and so on)?

Future research in methods for studying technology might seek to answer questions such as:

- How can we foster research through *and on* novel ways of blending technological innovation and design with ways of studying learning (i.e., linking design research or engineering research with learning research)?
- What will it take to develop and deploy more robust and multi-faceted views of validity, research quality, and/or trustworthiness? Tracy (2010) argued that in qualitative research, factors such as sincerity, credibility, and resonance are key dimensions of research quality. Emerging scholarship around learning with technology might take up, challenge, and extend these criteria for evaluating the trustworthiness of research.
- What are ways to cost-effectively inform research on rapidly changing technological assemblages that goes beyond techno-essentialism or slow methods such as large-scale RCTs?
- How can we conceptualize generalizability of findings regarding technology implementation given the rapidly changing social and technological contexts of learning? When should different generations of technological interventions be considered equivalent?

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