

Perspective

Five trends of education and technology in a sustainable future

Nicholas C. Burbules^{a,*}, Guorui Fan^b, Philip Repp^c

^a Department of Educational Policy, Organization and Leadership, University of Illinois, Urbana-Champaign, Urbana, IL 61801, United States

^b Institute of Education Governance, Faculty of Education, East China Normal University, Shanghai 200062, China

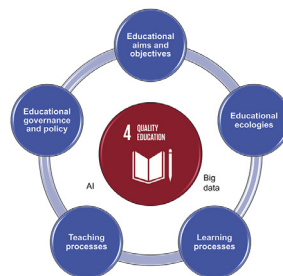
^c Office of Information Technology, Western Michigan University, Kalamazoo MI 49008-5200, United States



HIGHLIGHTS

- Education is key to sustainable development.
- New technologies in education are changing our ideas, conceptions, and aims of education, not only our methodologies.
- Each of these trends carries risks and dangers as well as new possibilities, and our reforms need to be developed with an awareness of both.

GRAPHICAL ABSTRACT



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ABSTRACT

Quality education is one of the pillars in the United Nations 2030 Agenda for Sustainable Development, which aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. This overall goal can be connected to some general trends affecting education in the information age. We argue that education is key to the future quality of human life and the sustainability of the world. Generally, education is being transformed in both formal and informal learning contexts by new digital technologies. Overall, some of these major innovations and how they are changing education can be summarized into the following aspects: 1) our educational aims and objectives; 2) educational ecologies and contexts of learning; 3) the processes of learning; 4) the processes of teaching; and 5) educational governance and policy. Meanwhile, we note some of the potential risks and downsides of these technology trends. From the sustainable perspective, our review points to a great potential for educational reform, but it can only be achieved if we are willing to rethink and even abandon some of our traditional ways of doing things in education.

1. Introduction

Sustainable Development Goals (SDGs) require an integrated reform of society, economy, and the environment (UN General Assembly, 2015). One of the pillars of these is Sustainable Development Goal 4 (SDG4): Quality education aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Education for sustainable development is crucial to this reform because education plays an essential role in environmental policies and practices which can promote ecosystem conservation and resource use (Van Poeck and Vandenabeele, 2012; Michael, 2020). Education is also one

of the calculated indicators of the Human Development Index (HDI), which is a fundamental dimension of sustainable development assessment (Korsakienė et al., 2011). Overall, education for sustainable development aims to find an effective solution for a multi-dimensional world. The digital transformation of the global economy and society is increasing the complexity of the modern world, as well as the speed of change, due to increased connectivity and an increase in the number of better educated individuals worldwide. These two elements—complexity and speed of change—mean that connecting education to the trends shaping the world we live in has never been so urgent (OECD, 2019). One of the leading challenges related to the future quality of life is education: not only because education is itself a pathway to a better quality of life, but because many of the other challenges to a sustainable future (population, employment, urbanization, and so on) directly impinge upon education and largely depend upon education if we are to cope with

* Corresponding author.

E-mail address: burbules@illinois.edu (N.C. Burbules).

them. Research emphasizes that education is the prerequisite to achieving other SDGs (Kioupi and Voulvoulis, 2019; Lewin, 2019).

Information technology is a driving force for educational reform, as well as a means of promoting shared knowledge in society generally. If you want to see a significant increase in educational productivity, you need to make fundamental structural changes supported by technology instead of mere “Evolutionary Tinkering” (He, 2011). The technology revolution in education can no longer be captured simply by looking at computers in the classroom. Most discussions have described computers as tools to be used as supplements to conventional instruction: for example, to use Ruben Puentedura’s SAMR model (SAMR stand for Substitution, Augmentation, Modification, and Redefinition), mostly as augmentations to conventional practice than as occasions for transformative *rethinking* of our methods and aims (Puentedura, 2015). Nowadays, only talking about digital textbooks or information and communication devices is too limited; these analogies are stuck in the language of past and current practice. The new revolution in Artificial Intelligence (AI), big data, and the so-called Internet of Things are all changing the way we work and live in almost every area of life; schools need to undergo a similar transformation. The information age has the potential to bring about the kinds of educational change that reformers have long pushed for, with schools becoming sites of critical collaborative inquiry and autonomous constructivist learning as individuals and groups work with new technologies to solve authentic problems under the guidance of a facilitative teacher (Lemke, 1998).

Sustainable education requires a sustainable development strategy, whose final objective is to achieve both personally and socially sustainable policies and practices (Chen et al., 2020). From the implementation perspective, educational activities, especially in schools, must incorporate sustainable and effective educational methods in order to fulfill the potential of technology transformation. We address here the following changes: 1) changes in aims and objectives; 2) changes in educational ecologies; 3) changes in our conceptions of teaching and learning; 4) changes that specifically affect teachers; and 5) changes in governance.

2. Changes in educational aims and objectives

The trend of world education has shifted to a more explicit focus on “21st century skills” or transversal competencies (Care, 2017). Within this broad framework, education for sustainable development helps students examine and reflect upon their professional responsibilities, capabilities, and personal motivations (Mulà et al., 2017). The popularity of technology is dramatically changing the skills needed in the labor market, from routine skills to performing tasks that require complex, high-level capabilities. This movement from physical tasks to creative, strategic, and analytical thinking is affecting what students need to master in school (OECD, 2015). These same capabilities are important also in other areas of life: active participation in citizenship, appreciation of literature and the arts, and rewarding interactions in daily social life (Eurydice, 2002). In English, people still talk about the 3 R’s: Reading, Writing, and Arithmetic (no, those don’t all start with R). More recently, people have started talking about the 4 C’s: Critical thinking, Creativity, Communication, and Collaboration (National Education Association, 2012). These new skills and dispositions rest upon a different conception of preparation for life and work: flexible capabilities related to learning to learn and adapting to changing demands, rather than specific subject-matter knowledge. The 4 C’s relate also to the ways learners need to learn to interact with new digital media: 1) the increasing need to critically assess the credibility of information accessed online; 2) interaction with a range of media and forms of expression, which digital natives both consume and create; 3) engaging with new forms of communication adapted to different kind of platforms, which suggest new models of literacy and fluency; and 4) social media and other applications that emphasize sharing and different forms of collaboration. And, finally, there are ways in which these 4 C’s relate to one another; they are

not discrete skills and dispositions. For example, communication skills are a crucial aspect of collaboration, critical thinking is necessary for effective communication, etc.

How radical a transformation would it require to reorient the curriculum centrally around these four elements: both as ways of changing the manner in which traditional subject areas would be taught, but also as distinct learning areas to be focused on themselves? How would the preparation and training of teachers have to change (for example, in itself being oriented more around these 4 C’s)? How would the forms of assessment and testing have to change (for example, in recognizing and rewarding collaboration and not only individual achievement)? How would our vocabulary about educational goals and the desirable characteristics of students change?

In addition, a crucial educational goal today is helping students have a better understanding of how technologies operate and the social and psychological effects they have. Part of that is a deeper understanding of AI, algorithms, and the assumptions built into intelligent systems. We are becoming increasingly aware that these assumptions, while necessary, can carry implicit biases and unanticipated consequences (for example, how facial recognition operates) that differentially affect different groups (O’Brien, 2019). More broadly, as more and more people—especially young people—rely upon Internet and social media as a source of information and learning, the more important it has become that they evaluate the sources and credibility of the information they receive. This sort of critical digital literacy is a growing educational imperative—one that, we believe, is not receiving enough attention in schools.

3. Changes in educational ecologies

Educational ecologies offer a framework for thinking about educational sustainability (de Castell et al., 2014). Another shift is changing our understandings of the spaces and contexts of learning. Despite all of the talk of technology transforming organizations and institutions, it could be argued that the organizations and institutions that relate to education have displayed less obvious evidence of change over the last few decades than those in other areas of society (Selwyn, 2012). Instead, people have often sought out educational alternatives outside the formal institutions of schooling: throughout the United States during the 1990s and early 2000s, a large number of Internet-based virtual schools were established to provide online “off-school” education. Many states in the United States support individual “online schools” and district-level online courses, in which 20% to 80% of students’ academic guidance can be delivered via the Internet (Watson et al., 2008). One way or another, it is estimated that more than one million American school students will take online courses each year—and those numbers will only increase (Means et al., 2009).

However, while the educational media have changed, the institutionalized school organization form is slower to adapt. Looking more closely at the growth of online and blended learning spaces, teachers and students interact synchronously and asynchronously through technologically mediated channels. In the simpler versions of online courses, the conventions and practices of regular classroom teaching (lectures, quizzes, and so on) are retained structurally but translated into a non-face-to-face forum. In more advanced examples, new and distinctive practices emerge within the online modality that do not always have a direct classroom-based corollary. Indeed, many instructors say that teaching online gives them ideas for reforming and revitalizing their conventional classroom teaching. MOOCs, for example, which were originally promoted as a new “delivery system” that could reach hundreds or thousands of students at low cost, but whose subject matter was very traditional in form and content, have proven to be even more significant as an occasion for breaking traditional models of teaching and learning.

Another potential shift in the spaces and contexts of learning involves increased use of visualization and virtualization technologies which en-

able the creation of a sensory learning environment that constitutes its own distinctive kind of space. Here as in other reforms, elements of gaming—which is so popular with younger people—cycle back as potential learning innovations. Issues of interest, engagement, and motivation look very different in creative visual and virtual spaces; furthermore, these capabilities also provide new affordances for how curriculum content can be displayed and explained. Augmented reality is a related innovation, where visual and virtual elements are grafted back onto ordinary spaces.

Finally, we might think about the potential of technologically mediated learning that is available anywhere and anytime: ubiquitous learning (Burbules, 2009). Here the learning environment is extended both spatially and temporally, and each of these previously described innovations—online, blended, visualization, virtualization, and augmented reality can play a part in how these distributed and ubiquitous learning opportunities can be made available: in the home, the workplace, the museum, the coffee house, the park or city street. Learning can become more contextual, situated in real life situations or problems or questions which suggests in turn different reasons for learning and a more organic relationship of learning to other needs and interests.

4. Changes in learning processes

Our discussion of new technologically mediated learning ecologies shows how each shift also entailed changes to the processes of teaching and learning. One dimension is the extent to which new technologies allow for greater personalization of the learning process. Psychologists tell us that the idea of different “learning styles” is a popular myth; but certainly students have different ways of engaging materials, different paces of learning, and different problems or difficulties they encounter in learning new subject matter. The standard educational model has always been an industrial “one size fits all” approach: mass schooling required it. New technologies allow for varying degrees of customization, and even a range of student choice, in how they engage new material.

One innovation with great potential is “adaptive instruction” (also called “intelligent tutoring”). The learner interacts with an online instructional program which is collecting data about their responses (and the responses of hundreds of thousands or even millions of other similar learners), then building analytical models of the patterns of answers, inferring what underlying conceptual error the learner is making, and then providing a customized tutorial or intervention specifically designed to help with that error or misconception. This innovation requires massive information about learner responses, and then AI-driven inferential models, based on certain patterns, to identify the underlying learning difficulties those patterns indicate. Adaptive instruction promises specialized support and scaffolding that could help to create a more equitable learning environment, given the diversity of learners and their special needs.

What we call here “ubiquitous learning” also entails changes to the learning process. When learning is becoming anywhere/anytime, we need to abandon the traditional distinction of formal and informal learning. There is still a role for planned structure and the role of skilled facilitators to keep people actively engaged, but now learning is more attuned to context, purpose, and needs (Sharples et al., 2016). This entails a shift from “curriculum-based” to “problem-based” learning, which in turn comprises a rethinking of the content, process, and motivations for learning. Learning in situated, ubiquitous contexts is more likely to be driven by immediate, practical questions and purposes. And this is related to another shift, between the typical “learn it now, use it later” model of much traditional learning, to what could be called “just in time” learning: accessing information, knowledge and skills for specific needs in specific contexts of use where those resources are immediately relevant and useful. Ubiquitous learning is also more social—even when the individual learner is alone. One of the striking things about many online learning resources is how they are thoroughly integrated with social media and social networks organized with and around that infor-

mation: the sociality of online information and learning resources is so pervasive that it is more useful to think of individual facts or chunks of information not as discrete pieces, but as nodes situated within social webs of meaning and purpose. Finally, another shift, which relates to all the others, is a shift from a teacher-oriented frame of reference, about what the educator wants the student to learn, to a learner-oriented frame of reference that focuses more on the needs, interests, and motivations of the student. One of the most striking aspects of putting online learning opportunities into the hands of learners is that they have far greater autonomy and choice about pursuing lines of inquiry that are interesting and important to them. Learning shifts from a more passive, recipient model to a more active, self-directed, co-constructionist model (Burbules, 2014a, 2014b).

One way to summarize these shifts is to think about how new technologies occasion a rethinking of the *when*, *where*, *how*, *what*, and *why* of learning. New technologies are not just tools or “delivery systems” for content—they are occasions for fundamentally changing the places and times of learning, the methods through which learning happens, the content of learning, and the motivational structures of learning.

5. Changes in teaching processes

These changes to learning processes and motivations also call for a rethinking of teaching strategies. When schools have large numbers of students, they need to develop a pedagogy that enables teachers to teach them effectively. Lectures are the easiest to implement because teachers only need to pass on their knowledge to students. In English there is an expression, the “sage on the stage”—the teacher as a source of authority and information, telling learners what they need to know. There continues to be a role for such teaching, but relying on this model alone squanders opportunities for innovation and using technologies to diversify instructional approaches (Collins, 2009). Over time this model has given ground to the “guide on the side”—the teacher as a facilitator of learning, knowledgeable in subject matter, but more skilled in guiding inquiry and problem-solving processes in which the learner discovers and creates new understandings for themselves. Not incidentally, this modality also means that the learner has a chance to master the processes of inquiry and problem-solving themselves, which provide the means for further, lifelong learning: to cite the old aphorism, teaching them to fish and not just giving them a fish.

Today we need to rethink both the “sage on the stage” and the “guide on the side” model in online learning contexts, not because they have become obsolete, but because we need to change their forms and strategies in the contemporary technological context. In order to continue to be effective as a lecturer, as a guide, as a mentor, or as a facilitator, and in order to continue to scaffold the processes of inquiry and problem-solving, teachers need to think again about what these activities mean in online, blended, flipped, and ubiquitous learning contexts.

One of the great myths of these new technologies is that they make teachers obsolete. They don’t, but they do make certain habits and ways of thinking about teaching obsolete. When teachers can adapt their strategies to the new affordances made available to them by these technologies, when they recognize that changes to the *when*, *where*, *how*, *what*, and *why* of learning also have direct implications for them as teachers, these new resources provide an opportunity and not a threat.

For a long time, teaching research and reforms in school practice have assumed that the core problem is how to help teachers teach more effectively. In this notion of “effectiveness,” teaching based on knowledge transfer has been the focus of research and practical reform. In the era of new technologies, there has been a greater focus on learning, and the processes by which learning can be supported and enhanced and only some of these processes exactly involve “teaching”. Traditional lecture teaching and training characterized by recitation, memory, and homework have gradually moved toward more autonomous views of learning that are more conducive to promoting student development, cooperative learning, social-emotional learning, and inquiry.

With innovations like adaptive instruction, teacher can work collaboratively with technology and data experts to help design learning environments that correctly identify learner difficulties and suggest instructional interventions that can help remedy them. The hands-on experience of teachers is an indispensable resource in understanding student learning as it actually happens; furthermore, teachers are expert in motivating and encouraging student learning, a crucial factor in educational success. In “flipped” classrooms, the point is not for technology to replace teachers, but to automate the processes that can be automated, in order to allow teachers to focus their energies, their talents, their creativity, and their experience on tutoring and support activities that can only be done by a live, engaged teacher. (One way to look at this is how to incorporate the 4 C’s—Critical thinking, Creativity, Communication, and Collaboration—more thoroughly into the teacher education process itself.) We need to get past the language of AI or technology *replacing* teachers, to talk about the distinct processes and resources they each provide in complement to one another.

6. Changes in educational governance and policy

In today’s educational systems, decision-making powers can be distributed across multiple governance levels: from national government and state governments, to provincial and regional governments, to sub-regional, inter-municipal and local authorities, as well as to school boards or even individual schools. Just as they have broadened the scope of the teaching and learning context, new technologies also have implications for new models of educational leadership, policy, and governance (OECD, 2012). One aspect is the potential of large data sets, and appropriate analytics, to generate useful information about student performance, problem areas, inequalities, and longer-term trend lines—at varying levels from the school to the nation. Too often educational policy decisions are based on following a fad or wishful thinking. Too rarely are they tested against real evidence of what is working and what is not working. New teaching and learning technologies, like social media and other resources, are powerful tools for data collection that tracks learner activities, successes, and difficulties. There are important privacy issues to be factored in here, we believe; but properly administered these avenues of data collection and analysis can yield information 1) to better target interventions to student needs; 2) to evaluate their effectiveness; 3) to track broader patterns of educational success and failure; 4) to assess the impact of policy changes; and 5) to hold accountable educational leaders with responsibility for the implementation and effectiveness of those policies. All of this could yield a revolution in transparency and public responsibility.

At a more personal level, educational leaders can use this information to guide their own decision-making and planning. But these new technologies offer other potentialities for leadership and governance as well: opening up channels of communication with parents and community leaders around school performance, engaging a wider conversation around school goals and priorities, keeping the parents of students better informed about what their children are studying and learning in school—and engaging them in an active partnership in reinforcing educational goals and projects in the home. Another aspect of “ubiquitous learning” is to break down the gap between “schoolwork” and “homework”—to create a more continuous flow of teaching and learning interactions across different spatial locations (school, home, museum, library, etc.).

7. Conclusions

Education has a catalytic effect on the well-being of individuals and the future of our planet. If we are to end unsustainable thinking and practice, we will need a transformed system of education to guide us into a prosperous and sustainable future. Here, we argue for a different orientation toward thinking about new technologies in education: not just as tools or delivery systems, but as a set of resources and affordances

that provide an opportunity to rethink our educational aims, methods, and institutions. The failure to engage this opportunity for rethinking is a constraint on the truly transformative potential these technologies possess.

At the same time, this rethinking has to have a critical dimension: not only what these technologies do *for* us, but what they do *to* us (Burbules, 2016). The shifting ground of potentiality beneath our feet can have both equal and unequal consequences. It can help remedy certain disabilities; or it can create *new* disabilities. It can be liberating or coercive, and it raises new questions about surveillance and privacy. AI can be human-centered, or threatening; it can even challenge the boundaries of what it means to be “human”. In all of this, new technologies in education can enhance the future quality of life—or become a new kind of challenge and difficulty. In the end, we suspect, it will have some elements of both, and we need to be prepared for that. We need to recognize the limitations and boundaries of artificial intelligence as well as the potential advantages of artificial intelligence in knowledge storage and procedural activities. At the same time, we need to recognize human beings in terms of flexibility, creative work, and work related to value, belief, and emotional support. Given the inevitability of artificial intelligence as a feature of human life, it is necessary to strengthen laws and regulations, ethical standards, and public policy norms related to artificial intelligence, so that these new potentialities operate within a broader framework of human intelligence, human purposes, and human norms and values. We need a new humanistic spirit adapted to a technology-shaped world. This review provides a dialectical vision for reforming education within the forward-looking framework of sustainable development.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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