Futures 113 (2019) 102422

Contents lists available at ScienceDirect

Futures

journal homepage: www.elsevier.com/locate/futures

The digital frontier: Envisioning future technologies impact on the classroom

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A R T I C L E I N F O

Keywords:
Artificial intelligence
Augmented reality
Smart materials
Educational technology
Education futures
Education

A B S T R A C T

Global advances in technology and information are purportedly propelling transformations and disruptions across many sectors, including education. However, historical reviews of technology integration in education mainly reveal weak or ineffectual impacts on learning, and only minor reforms to date within the education system. This study adopted a futures studies methodological approach to explore how K-12 educational spaces and experiences might be shaped by emerging and emergent technologies. In this regard, a series of vignettes are presented which critically examine the potential of augmented reality technologies, artificial intelligence, and smart materials technologies to transform future learning experiences and learning environments across K-12 education contexts, while also challenging assumptions about, and considering influences on, these futures. The focus of the study was not to predict a single or desired future for education, but rather to critically consider a range of possible education futures informed by the articulation of these three vignettes. The paper concludes with discourse on an emergent pedagogic approach that has the potential to prepare teachers and learners to interact and flourish within radically reconfigured learning spaces that lean on the aforementioned technologies to support transitions within and beyond the school and its connected communities.

1. Introduction

This paper offers critical insights into the potential of emerging and emergent technologies in transforming education spaces and experiences through the lens of a futures studies approach. While futures studies as an academic discipline may be better known in business, economics, global politics, and hard sciences, the field has much to offer in futures exercises within the context of education. Wendell Bell (1997) states that the purpose of futures studies is to "discover or invent, examine and evaluate, and propose possible, probable and preferable futures" (p. 73) while Malaska (2000) describes futures research as "nothing else but refinement of the every day futures thinking, i.e. perceiving and envisioning reality." (p. 239). A key challenge that arises across all contexts of future studies is the inherent difficulty in attempting to solve ill-defined complex problems. An example in education futures in this regard would be the difficulty in "preparing" educators, learners and other stakeholders for engagement in types of future learning spaces or experiences that may be dramatically different to what exists or what is practiced today. Sardar (2010) first law of future studies asks

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https://doi.org/10.1016/j.futures.2019.04.009
Received 5 November 2018; Received in revised form 25 April 2019; Accepted 29 April 2019
Available online 01 May 2019

that we embrace the complexity and uncertainty at the core of these challenges, because by definition the problems future studies aim to solve are wicked and embedded in landscapes that are constantly changing. Sardar (2010) second law of future studies states that the most viable outcomes require mutually assured diversity. Therefore, a futures studies approach brings with it an understanding that the problems are often not easily resolved, that is, there is no one solution. Thus, a sustained effort is required to develop possible future scenarios based on fringe technologies, emerging trends, and probability. This inherent skepticism of a single or definite solution is reflected in Sardar (2010) third law of future studies, which states no one proposed future or solution can ever be accepted on face value, instead we should be skeptical of simple or dominating predictions that attempt to foreclose the future. In his fourth and final law of future studies, Sardar (2010) states that "since we can have no true knowledge of the future, the impact of all futures explorations can only be meaningfully assessed in the present" (p. 184). This law proposes that we can never truly know or accurately define the future, but rather we should be open to other options or possibilities. It is with these laws in mind that we have developed the methodological approach of the paper, as outlined in the next section.

2. Methodology: a futures studies approach

While the study sits within a critical future-studies theoretical frame that seeks to understand how the future of K-12 educational spaces and experiences may be shaped by emerging and emergent technologies, the focus of the study was not to predict a single or desired future for education, but rather to critically consider possible futures informed by the articulation of three vignettes which critique the present. Therefore, there appears to be a natural fit (and philosophical appropriateness) to approaching this study through a futures studies lens. The study sought inspiration from the Six Pillars conceptual framework (Inayatullah, 2008), which details six processes that can be used to guide practices in futures studies, namely, mapping, anticipation, timing, deepening, creating alternatives, and transforming. From these processes, Inayatullah (2013) usefully derives the following simple questions, which in turn constitute the abridged method employed in exploring and critiquing possible futures that informed this study:

1 What is the history of the issue? Which events and trends have created the present?
2 What are your projections of the future? If current trends continue, what will the future look like?
3 What are the hidden assumptions of your predicted future? Are there some things taken for granted (about gender, or nature or technology or culture)?
4 What are some alternatives to your predicted or feared future? If you change some of your assumptions, what alternatives emerge?
5 What is your preferred future?
6 How did you get here? What steps did you take to realize the present? …
7 Is there a supportive narrative, a story? If not, create a metaphor or story that can provide cognitive and emotive support for realizing the desired future. (p. 60)

The methodological approach in this study was informed by the first three of these questions. In this regard, the histories, events and trends that set the context for exploration of open learning spaces and technologies in education are explored. Furthermore, a series of vignettes are presented which examine emerging and emergent technologies (augmented reality technologies, artificial intelligence and materials technologies) in the context of future learning experiences across K-12 education contexts, while also challenging assumptions about, and considering influences on, these futures. Finally, the assumptions underpinning our vignettes were critically reviewed and deliberations on these included within the latter section of the paper. The research on the remaining four questions is currently underway, and is being informed by stakeholders from differing contexts who are challenging and will inform our ultimate arrival at "possible or desired" educational futures, and our back casting to the present. This will form the basis of a separate paper at a point in the (near) future.

3. Vignettes of technology use in the classroom

This section opens with a historical overview of technology integration in education. This is followed by a critical exploration of three technology vignettes which explore their current uses in, and potential for teaching and learning, while avoiding as Facer and Sanford (2010) advises, making simple assumptions of what will happen, or to discuss what we "want" or "will make" happen. For the purposes of this paper, the technologies underpinning our critique of education futures in each vignette have been categorized into three domains, with the first being open learning spaces (physical learning spaces of the future), the second domain is tangible technology (the broad category of digital tools that a person can interact with such as augmented reality (AR) technology), and the third domain is intangible technology (technology not visible or touchable by itself such as artificial intelligence). It is worth noting that each vignette is approached with the understanding that it serves as an illustration of just some practical uses, or potential applications, of emerging and emergent technologies in education-related contexts.

3.1. Historical overview of technology integration in education

Over the past several decades there has been no shortage of lofty claims and predictions of the untold profound impact that new technologies would have on education and learning in the classroom. (Howard & Mozejko, 2015) critique of a decade of integration of technologies in education usefully frames three waves or "ages" of technology integration: the pre-digital age (1890s–1970s), which heralded the integration of audio and television (broadcast-type) technologies, the personal computer age (1970s-present), which introduced personalized tutoring systems and digital games, and the Internet age (1990s-present), with its constantly evolving networked forms of learning and new capabilities including content tagging and annotation, geo-location, bio-sensory captures, and crowd sourcing data. While each age of technology integration brought new and innovative ways to connect people, information, and learning, scholars generally agree few (if any) have reached their anticipated potential. Gregory et al. (2014) argue that the rhetoric that often accompanies the emergence of new technologies with respect to inflated expectations of their likely impact on learning, typically conforms to Gartner's Hype Cycle which post-implementation moves to the "Trough of Disillusionment" up to the "Slope of Enlightenment" and onto the "Plateau of Productivity" (p. 287). Thus, the integration of new technologies in education is typically followed by a period of realization that there exists a gap between reality and expectations, and this moves to a period where there is more critical consideration of the effectiveness or otherwise of the technology. Howard and Mozejko (2015) further argue that reforms have primarily focused on how these technologies can increase efficiencies within the system, increase the numbers accessing education, and ultimately progress neoliberal agendas that value accountability and productivity within learning, and preparedness of learners for the workplace. Cuban (2001), Hicks (2012) and Howard and Mozejko (2015) recognize that the third age of the Internet has brought widespread integration of digital technologies in the classroom, but recurring issues of low teacher confidence and lack of adequate training for teachers (that exist across the ages) mean that there continues to be a barrier for meaningful integration of technology in education leaving us short of the promised revolutionary change to teaching and learning practices. A key issue highlighted by Charalambos (2014) is that educators do not integrate new technologies into their classroom as would be expected and in fact many are simply using new digital tools in the same way as the tools that were replaced. Therefore, in line with Saari and Säntti (2017), it would be remiss not to recognize the historical, ideological and social structures of schools, and embedded cultures and know-hows in teaching and learning therein, which the evidence would suggest has been remarkably resistant to change (particularly with respect to adoption and integration of new technologies in learner-centric ways) up to the present day. Selwyn (2011) noted in his publication exploring issues and debates in education and technology that "any technology must be seen in terms of the limits and structures that it imposes as well as the opportunities that it may offer for individual action and agency" (p. 8). Thus, it is important for us to remember that technologies are not neutral entities, they are values-laden, and become culturally embodied when integrated in practices, and thus, have the capacity to be used in ways that restrict or transform learning.

3.2. Vignette 1: opening learning spaces

The concept of open learning spaces can be traced to initiatives in post-war Britain that culminated in the launch of the Children and their Primary Schools Report in 1967 (The Plowden Report, 1967) which opened the way for informal and open learning in British primary schools (Cuban, 2004), with the broader "open classroom" movement really taking hold as an attempt to reform education in the late 1960s and 1970s, particularly in the United States. The typical 1960s school architecture manifested in buildings where learning was organized to "take-place" in dedicated (inflexible) physical spaces for learning, separated from spaces for dining and play; reminiscent of those that existed from the Industrial Age. These fixed, authoritarian constructions reflected underpinning insular beliefs about the purpose of education being the transmission of knowledge and the preparation of a workforce, while also seeking to re-enforce conformance of learners to dominant hierarchies, further compounding issues of exclusion and inequality within societies. The "open classroom" movement sought to reform and enrich educational practice by re-designing the architecture of schools to include more open and flexible spaces that allowed for teachers and learners (at varying grade levels) to interact and collaborate at the same time, and by integrating activities that enabled learners to learn from and with each other. Horwitz (1979), as noted by Alterator and Deed (2013), perhaps best encapsulates the open classroom as a "style of teaching involving flexibility of space, student choice of activity, richness of learning materials, integration of curriculum areas, and more individual or small-group rather than large-group instruction" (pp. 72–73).

Historically, there were challenges in realizing the true potential of open classrooms, both in terms of their physical architecture and also in the resultant quality of the learning experiences. In terms of the open classroom architecture, some key issues identified included their susceptibility to noise, distractions, and disciplinary interruptions, resulting from a range of factors including: the absence of walls to reduce noise amplification, issues in having large gatherings of learners in a single space, and the lack of teacher readiness for practice in shared open spaces. With respect to the latter, Osborne (2016) points to the issue of many teachers not being prepared for engagement in open learning contexts and instead preferring to conform to Hood (2015) "paradigm of one"; "…one teacher, teaching one subject to one class of one age using one curriculum at one pace, in one classroom for one hour" (p. 13). By the 1980s, many schools in the US had re-configured open classrooms back into traditional classroom formats. However, the call for more open forms of learning spaces didn't abate, and by the turn of the millennium, new school building programs such as the United Kingdom's Building Schools of the Future program 2003–2010 (Department for Education & Skills, DFES., 2003), were initiated with a view to providing more progressive school architectures, re-opening the open classroom debate which continues today. With recent advancements across a broad range of educational and materials technologies, there are new opportunities to re-consider physical and learning architectures for schools of the future that may lend themselves to more flexible and open models of learning, and in doing so, support more diverse and inclusive forms of learning, and more enriching learning experiences such as those initially conceptualized within the "open classrooms" movement (Alterator & Deed, 2013; Melhuish, 2011; Nair & Fielding, 2005).

Alterator and Deed (2013) argue that the forms of "architecture" that support "open classroom" contexts requires the design and construction of learning spaces that are non-hierarchical, multi-functional, blended within physical and virtual spaces, student centered, and allow for restructuring of traditional boundaries between formal-informal learning, the teacher-student, and the classroom-home. Newly emerging smart materials and sensory structures represent real opportunities to redress issues with lighting, noise and configuration, and to support the physical realization of authentic forms of open learning spaces in the future. Smart materials and sensory structures take the form of (engineered) materials that have “memory” of previous beneficial states and can conform to these where appropriate. In this regard, they have sensory capacities that allow them to respond appropriately (adapting and regulating function) to environmental conditions and or events. Examples of these emergent technologies include: smart concrete (that can enable detection of stress fractures or indeed people movement within a building); smart bricks (that can detect stress fractures, relay information about moisture, humidity and temperature); smart wrap (futuristic building material that replaces all interior and exterior materials, providing climate control, power anywhere on walls and allowing for re-configuration and movement to new locations at any time); smart glass (changes from transparent to opaque, thus enhancing privacy); smart green roofs; smart composites; smart paints and coatings, and sound absorbent materials to control for optimal acoustic conditions (Arenas & Crocker, 2010; Yousef Mohamed, 2017).

The power of these materials in the aggregate is that they can support the creation of sensory structures that can monitor, control, and enact appropriate responses to environmental and other stimuli in open learning contexts at the level of the whole-building structure. This may include noise level management across multiple learner groupings through the use of new forms of absorbent materials in ceilings or floors, or the provision of much-needed flexibility and privacy within the physical architecture of open learning space through deployment of smart glass “partitions” (that can be switched to transparent or opaque depending on the nature of engagement) within the open space. Furthermore, some of these structures will have the added advantage of being able to be dismantled and re-built in another location, such as a forest, and thus can be used to provide extended authentic learning opportunities beyond the school campus. Therefore, these smart systems can be used to provide a healthier and more sustainable physical environment, responsive to changes in local climate and in conserving energy, and in moderating noise levels.

While the use of the aforementioned smart materials and structures presents a transcendent opportunity to enhance the physical sustainability of the building, as well as foster opportunities to maximize the enhancement of teaching and learning, it is important to note that many of these smart materials and (intelligent) structures are still in various stages of prototype and testing. It may be some time before their true potential or limitations can be authenticated. Furthermore, with increasing public concerns about climate change and demands on governments to be responsive to the UN’s Agenda 2030 for Sustainable Development (United Nations Sustainable Development Goals Knowledge Platform, n.d.), certain forms of materials development reliant on non-renewable materials may likely be subject to new environmental restrictions which limit the type or composition of materials that can be used within construction of school buildings, restricting opportunities for integrating smart materials and or systems in the aforementioned open learning spaces.

Finally, as already noted, the success of open classrooms centers on the extent to which participants (both teachers and learners) can meaningfully engage within the myriad of learning possibilities offered therein, and thus is very dependent on teachers being encultured into new ways of being and facilitating learning within these spaces. In their case study of teachers working within an open classroom model in Victoria, Australia, Alterator and Deed (2013) highlighted two key themes contributing to teacher’s successful utilization of open classroom architecture: teacher perceptions of the affordances of open spaces (flexibility, increased visibility, scrutiny of learner interaction, and the de-emphasis of hierarchy) and teacher reaction to open spaces (collective practice, team orientation, interactions and authority). The results of the case study provided evidence that open spaces allowed teachers to dynamically re-think how time and space could be used in teaching and learning. Furthermore, there was evidence that teaching teams formed within the schools as a result of teachers having to ‘share’ facilities as well as increased opportunities for them to informally connect with each other. Ultimately the open spaces prompted a shift from individual forms of thinking to more community-oriented frames of mind and reduced formality in teacher-teacher and teacher-student interactions, thus de-emphasizing the hierarchy and promoting more democratic forms of learning. However, Osborne (2016) makes the point that both the practices of teaching and learning, and the learning spaces need to be re-considered in order to “achieve more inclusive, equitable outcomes for learners” (p. 4). Osborne (2016) outlines a range of considerations that need to be accounted for in order to achieve workable open learning spaces, including ensuring: inclusivity of environment, its cultural responsiveness, variety in and clear purpose for the learning spaces, and active learning and physical movement fostered within learning spaces. In a case study examining the ambient, intrusive and background noise of an open plan Kindergarten classroom containing 91 students, compared with an enclosed classroom of 25 students by Mealings, Buchholz, Demuth, and Dillon (2014), the results showed much higher intrusive noise levels in the open plan classroom, with signal-to-noise ratios and speech transmission index scores well below those recommended in classrooms. In a further publication, Mealings, Demuth, Buchholz, and Dillon (2015) suggest that open spaces may not be appropriate for all learners, noting that noise levels may negatively impact critical listening activities for younger learners.

To conclude this vignette, the degree of flexibility required to successfully implement and blend more open forms of learning can be culturally and logistically challenging for teachers and learners, and will require re-imaginings of future architectures of, and pedagogies within, these learning spaces. While the open classroom architectures have the potential to counter the negatives of closed, authoritarian model of industrial-era classrooms, more research is needed on the transformations (cultural or otherwise) required for teachers (and learners) re-orienting themselves to the translation and expression of openness facilitated within these new learning spaces, and critique of same.

3.3. Vignette 2: augmented reality (AR)

Augmented reality or AR as it is commonly referred is a technology that facilitates the superimposing of virtual objects onto the real world through a combination of lens and display technology. AR is one specific technology in a suite of technologies known as mixed reality (MR), which also includes virtual reality (VR), 360-degree video and holograms which allow the combining of physical and digital dimensions. In contrast to virtual reality, in which the user is completely immersed in a virtual world and has no perception of the real world, AR uses the real world as its source and overlays virtual objects so the real and virtual appear as one to the user (Akçayır & Akçayır, 2017). The combined virtual and real worlds are viewed through a screen, on desktop computers, or now more commonly, on mobile device screens and in headsets. Emerging as a training tool in the 1990s, its use in educational settings has increased dramatically in recent years and several comprehensive literature reviews have been published which document the range of uses of AR across primary, secondary and tertiary education (Akçayır & Akçayır, 2017; Bacca, Baldiris, Fabregat, Graf, & Kinshuk, 2014; Chen, Liu, Cheng, & Huang, 2017). While this vignette draws upon these literature reviews and other articles on AR in education, it does not represent a systematic review of literature to date. A search for journal articles indexed by the Web of Science returns 77 articles published before 2014, and 242 published from 2014-present, indicating a massive rise in the research in this area, and illustrating that a systematic review of the complete literature is beyond the scope of this vignette. Instead, literature was selected which provides an overview of the evolution of AR, applications of AR in K-12 education, the advantages and challenges in using AR in education, and future directions of AR use and research in education.

The Future Today Institute 2018 tech trends report describes AR as the mixed reality technology which has "the greatest market potential for organizations in the near-future" (Future Today Institute, 2018, p. 136). Perhaps one of the most common educational applications for augmented reality is AR books. The basic principle is that an AR book is a physical book which contains images that when scanned by a device camera and recognized by the AR application, triggers the display of augmented resources including images, video clips and 3D models as overlays onto the screen. More recent instances of AR books also allow interaction by displaying buttons that when "pressed" by the user can manipulate the information displayed, as well as supporting natural language recognition to control the application (Lytridis, Tsinakos, & Kazanidis, 2018, p. 2). The nature of this functionality has led to AR books being named "interactive 3D pop-up books" (Altinpulluk & Kesim, 2016, p. 4114). AR books have been developed for all ages of learners; classic and contemporary fairy tales are available and are aimed at younger children, while AR books which focus particularly on the sciences have been developed for secondary high school students.

While AR applications have been used across various subject areas, applications in the sciences are in abundance, with Bacca et al. (2014) reporting that over 40% of the educational AR studies they reviewed focused on "Science". Common applications for AR in the sciences include 3D modelling, often of abstract or hard-to-visualize concepts, such as those documented in the research of Shelton and Hedley (2002) who state that "AR has the potential to transform instruction and learning of complex spatial concepts and content" (p. 7), using AR to teach students about the relationship between the sun and the earth, and concepts such as rotation versus revolution, and solstice and equinox. AR has also enriched the field of mobile learning and supports the concepts of discovery-based learning and situated learning. For example, Chang et al. (2014) examined the use of an AR mobile guide to enrich the appreciation of painting in an art museum, illustrating the enhanced "interaction between the additional, virtual information and the real exhibits" (p. 186). Finally, there is a growing body of literature on Augmented Reality and Game Based Learning (ARGBL). Two literature reviews of ARGBL in education examine how the use of AR games in education can create a deeper connection to the material and develop skill or concept mastery (Fotaris, Pellas, Kazanidis, & Smith, 2017; Pellas, Fotaris, Kazanidis, & Wells, 2018) in the hope of engaging students through emulating the success of AR games such as Pokemon GO!

In their review of selected literature between 2003 and 2013, Bacca et al. (2014, p. 140) reported that the main documented advantages of AR in educational settings were learning gains and motivation, supporting research by Di Serio, Ibáñez, and Kloos (2013), Liu and Chu (2010) and Chang et al. (2014), which specifically examined the impact of AR on learning outcomes and learner motivation and enhanced students' learning performance. On assessing the documented effectiveness of AR, Bacca et al. (2014) noted that most of the research they examined found that using AR led to better learning performance in educational settings, with learning and student motivation also reported as significant benefits (p. 142). Furthermore, two studies indicated that in using mobile AR guidance, student engagement and performance is enhanced (Chang et al., 2014; Liu & Tsai, 2013), and the learner is placed at the center of the classroom experience, facilitating student autonomy, and increasing their agency in taking responsibility for the trajectory of their learning (Munoz-Cristobal et al., 2015). Other benefits identified included improved perceived enjoyment when learning, positive attitudes to the educational activity, and providing possibilities for interaction and collaboration, with many of these benefits being attributed to the graphical content and level of interactivity offered in AR applications (Bacca et al., 2014, pp. 142–146).

While the aforementioned examples illustrate the benefits of using AR in education, it is not without its challenges. Most of the documented challenges of using AR technology in learning are related to the technological limitations of AR at present such as positional tracking, content placement (mapping), user-friendly interfaces, and lack of higher quality productions (Bacca et al., 2014; Chang et al., 2014; Pellas et al., 2018). Another major limitation of AR adoption in education is the lack of an educational platform in which educators can create customized contextually relevant experiences for their class or subject area as well as the need for a substantial amount of time working on the pedagogical value of AR and preparing activities which include the use of AR in an effective way (Munoz-Cristobal et al., 2015). Without the ability to create authentic experiences, this technology may be seen as a "gimmicky" solution, and the novel nature of the technology might overshadow the desired learning (Pellas et al., 2018, p. 14; Bacca et al., 2014, p. 141).

While the application of AR has been widely documented in primary, secondary and higher levels of education, very little research has been carried out on the potential role of AR in early childhood development or on its potential implementation in special needs education (Bacca et al., 2014; Akçayır & Akçayır, 2017; Pellas et al., 2018). Underuse in early childhood settings is no doubt linked to the lack of consensus in this area of research on the appropriate amount of screen time for young children (Burton & Pearsall, 2016; Christakis, 2014). Pellas also notes that AR in teacher education is one of the areas which is least explored (2018, p. 146); if this indicates that educational applications of AR are simply not well explored in teacher education programs, this might give cause for concern that this technology may fall short of the lofty claims that it will change the landscape of the future classroom, or that it will persist through the hype cycle of technology.

The Futures Today Institute reports that "in 2017, every major tech company, from Alphabet to Facebook to Snap, made big announcements about investing heavily in the future of AR" (Future Today Institute, 2018, p. 136). Magic Leap is one of the companies leading innovation in AR technology and claim to be pushing AR into the interactive zone, where users will not only experience digital content on top of their real world but will be able to manipulate and interact with it. Magic Leap One (their AR headset) along with other devices such as Microsoft HoloLens (and Kinect Project for Azure) present exciting and numerous potential applications for education. These developments offer the potential for personalized learning through AR applications. This possibility is particularly evident if AR systems interface with other technologies such as individual learning profiles, sensor feedback which can analyze physiological responses, as well as artificial intelligence which can analyze student learning and alter their learning trajectory accordingly. The integration of this suite of technologies under the umbrella of a "next generation" AR experience has the potential to transform learning from passive "look at" activities to "do" activities, which will enable tailored deep learning, as well as enhance student autonomy and agency.

Although there still remains high hopes and expectations of AR in education, as with any new technology and its integration into education, there are a number of challenges and external forces that can impede the adoption. Assuming AR can overcome the direct technological challenges, it is still unknowable to foresee how or if our society will continue to maintain the belief that technology has a valuable, not destructive role to play in education, that funding will continue to be provided to support the successful integration of AR into education, and that individuals and partnerships which represent a balance of technological, content and pedagogical knowledge will continue to engage with one another to develop pedagogies for effective teaching and learning.

3.4. Vignette 3: artificial intelligence (AI)

Artificial intelligence or (AI) has become such a touted buzz word around the future of technology that regardless of domain, you cannot escape the bipolar hyperbole of the limitless potential or impending existential crisis this technology will usher to the human race. Artificial intelligence has become such a prolific focus of future technologies that Google has gone so far as renaming their "Google Research" brand to "Google AI" noting that everything Google works on is incorporating some level of machine learning techniques (Howard, 2018). The educational sector is no exception. In fact, AI has been proposed at numerous times in the past 30 years as a solution for enhancing learning though the development of intelligent tutoring systems (ITS) allowing a computerized system to present material in a flexible, learner-centric way that addresses all of the idiosyncratic needs of the students while simultaneously being able to make sound pedagogical decisions on how best to "teach" the student (Beck, Stern, & Haugsjaa, 1996; Luckin, Holmes, Griffiths, & Forcier, 2016). It is worth noting that although an AI powered ITS solution has been proposed for over three decades, one has not yet arrived to market.

In this vignette, we look to the current and emerging trends in AI research to better understand how AI development may lead to a probable or preferred impact on the future of educational technology and what factors may militate this technology. Taking a high-level overview of AI, it is commonly defined as machine intelligence which is demonstrated by a non-living entity compared to natural intelligence as displayed by humans and other living species. Given the difficulty to accurately define a global scale of "intelligence" the broader community of AI researchers have defined three stages or epochs of intelligence based on the comparison of machine intelligence to that of human intelligence. A succinct overview of the three epochs of AI from Dickson (2017) state the first stage known as artificial narrow (or weak) intelligence is the stage we are currently experiencing. Within this first stage of narrow AI machines are able to compute complex algorithms and perform independent (unsupervised) machine learning to achieve a single goal or task. The modern conveniences of digital assistants, computational photography, predictive suggestions, and even self-driving cars are all considered examples of narrow AI. The second epoch of AI is artificial general (strong) intelligence. It is this general AI stage in which machine intelligence is set to rival that of natural human intelligence. In this stage, machine intelligences would have the capability to make complex decisions, have their own perceptions, multi-task between unrelated thoughts, and create authentic memories that influence subsequent decisions. The third and final epoch is referred to as artificial super intelligence. This final stage of AI is classified as the time when the machine intelligence has surpassed that of human intelligence and is able to perform complex original thoughts and creativity that surpass the capacity of humans (Dickson, 2017).

Many technologists, researchers, and economists have described the developments of AI as the third era of computing which has propelled us to the brink of the Fourth Industrial Revolution as a result of advancements in machine intelligence and previously unimaginable scale of Big Data (Cukier & Mayer-Schoenberger, 2013; Schwab, 2016). The Fourth Industrial Revolution is marked by the convergence of physical, digital, and biological technologies that not only change how or what people do, but changes what it means to be human in contrast to the proceeding three Industrial Revolutions marked by steam, electricity, and internet communication technologies respectively. This new technological disruption has been predicted to lead to an expansion in technologic advancements leading to economic growth and has also been marked with caution as the same advancements may also lead to greater economic inequality and disruption of existing labor markets (Schwab, 2016).

While the debate of the merits of this new era of AI are far from over (and marked by celebrity-status technologists on both sides of the argument), a strong cautionary argument has been made by a leading AI researcher Nick Bostrom, Professor at the University of Oxford. Bostrom has been outspoken about the potential existential dangers of developing artificial superintelligence, and is credited with the infamous thought experiment, the Paperclip Maximizer (Bostrom, 2003) in which he employs an entertaining reducto ad absurdum to hypothesize the dangers of a super intelligent AI that has surpassed the control of the human creators. In this thought experiment, the premise is simple, the AI is given a directive to maximize the production of paper clips. With no moral considerations, all obstacles are removed and all resources aligned to maximize the production of paperclips no matter the consequences. The unforeseen outcome of this AI gone wild is captured humorously by Yudkowsky (2008) with the quote, "The AI does not hate you, nor does it love you, but you are made out of atoms which it can use for something else" (p. 27). According to Bostrom (2015) 50 percent of the top AI researchers predict that AI will reach the level of general (or strong) intelligence by the year 2050 and 90 percent predict that general AI will be reached by 2070. While those dates are still several decades away, the growth of AI research and development is accelerating and it remains a critical imperative to understand what AI is currently capable of, what it will be capable of, and how can the future of this technology be built in a socially-responsible way, less we become the fuel for paperclips so to speak.

Turning the focus back to the future of educational technology, it is clear that the development of AI has the potential to disrupt the relationship between the learner and technology. One such advancement is the "datafication" of our daily activities in which all elements of our digitally-enhanced lives becomes quantified by our location, communication, and usage data etc. (Cukier & Mayer-Schoenberger, 2013). It is argued that this datafication will allow machines, and systems to extrapolate an unprecedented level of individual knowledge of students and thus intelligent systems would be able to provide highly personalized real-time learning activities, assessments, and interventions as needed. In a recent paper, Almohammadi, Hagras, Alghazzawi, and Aldabbagh (2017) formulate that customized, personal adaptive learning systems would save time, provide real-time contextual pedagogical assets that would enhance the learning experience. An increasing concern around the datafication of users' behavior is privacy. In the era of big data, it has been cautioned that a reconceptualization of privacy is needed to better understand and limit use of personal data (Mai, 2016). Growing public concerns about personal data use and misuse have the potential to stall the advancements in AI systems and will continue to be at the heart of future discourse around the ethical development and use of AI in educational systems. In response to this concern educational institutions are responding by committing to further research as evident in Massachusetts Institute of Technology's (MIT) investment of $1 billion dollars towards researching the ethical development of AI (Krishna, 2018).

Advancements in AI that have a direct aim of enhancing the teaching and learning experiences in education can be classified as a sub-domain known as artificial intelligence in education or AIEd. AIEd is described as the powerful collection of tools used to formulate a deeper, more granular understand of how learning actually happens at the individual level, going beyond cognitive understanding, and considering all of the socio-economic, cultural, and physical contexts (Luckin et al., 2016). In their publication, Luckin et al. (2016) describe three models of knowledge that are at the heart of AIEd; the pedagogical, knowledge, and learner model. Taking a closer look at the AIEd models, the pedagogical model represents the knowledge and expertise of teaching in which specific areas of knowledge are represented to provide the learner with the best possible learning experience. In the pedagogical model for example, this might contain precise knowledge on productive failure, knowing how long to let the learner make mistakes, or allow them the freedom to explore a concept before being "informed" of the correct or desirable outcome, or knowing what feedback to give and when, based on the learner's actions, and knowing how to accurately assess the learners progress or mastery of a concept. The knowledge model represents the collective knowledge of a specific subject area such as mathematical laws, historical facts, and languages. The learner model likewise contains the knowledge of the individual learner including their historical successes and failures, emotional states, engagement, interests, and goals. The potential power of these systems is evident when considering the collection of that data at scale across students all over the world to be used in continued development of the pedagogical approaches, based on feedback gathered by understanding how the learning took place, where the misconceptions lay, and how best to deliver the needed interventions.

The advancements in AI and the impact on educational technology is not without its share of cautionary models. With the increasing role of AI and unsupervised machine learning through big data, one of the "red flags" raised is the potential for the student-teacher relationship to be altered and if not done carefully, diminished. A recent thought experiment on this idea resulted in the hypothetical result of students becoming estranged from their teachers as the role of teacher continued to shift to a diminishing role of "guide" rather than directly teaching to such an extent that the relationship all but vanished and replaced by a student-AI type model (Guilherme, 2017). Thought experiments, and cautionary tales of similar proportion are fun to engage the mind, but also serve as a reminder that as the technology evolves it remains of critical importance to keep track of the advancements and ensure that the AI is working to support the ideas and directions of humans and not be the entity directing those changes. Luckin et al. (2016) support this notion of participatory design by suggesting that the role of teacher will change with the advancement of AIEd and require new skillsets including sophisticated understandings of the AI, research skills to interpret the data, and new management and team-working skills that can leverage the new systems.

The Future Today Institute (2018) discusses the continued development of AI in their annual Tech Trends Report and forecasts the implications for educational technology such as the development of cognitive computing, systems that utilize natural language processing to understand our (human) intentions and provide interactions in a more natural way. Newer more powerful cognitive systems are forecast to be built to assist knowledge workers in education, medical industry, and any field in which knowledge and information play a critical role. This development has direct implications for learning with technologies, as the digital assistants become ubiquitous and smarter they will be able to work alongside adaptive learning systems to provide better individualized learning experiences for students and allow teachers and administrators to have a much deeper understanding of the students' understanding of complex subjects and or topics.

To conclude this vignette of the potential impact of AI on the future of educational technology, we must also consider the global extrinsic factors that may accelerate or deter the advancements discussed. As with all futures, it is inherently unpredictable and open-ended. The global factors that may alter the direction of AIEd may include the global economic impact of the fourth industrial era. Public perception of these new advances in technology may also have unforeseen impact on the development of AI. Advancements in AI are not always met with open arms, and in fact are at times met with open hostility and anger as reported in a recent newspaper article that Waymo self-driving cars (Waymo is a Google spin-off driverless car company) were physically attacked by residents of Chandler Arizona in the United States. It was reported that the autonomous cars suffered tire slashings, rocks and other debris being hurled at the cars, as well as other motorists trying to run the vehicles off the road, and even threats of physical violence to the in-car-safety driver (Romero, 2018). While there can be many claims of how the advancements of AI will change the future of educational technology, the reality is this future is unwritten, and susceptible to a growing number of global variables that will determine if and how we reach a preferred future where advanced technologies can enhance the experience of teaching and learning.

4. Discussion and conclusion

When considering educational futures, such as those encompassing open forms of learning spaces, augmented technologies and artificial intelligence, we need to be mindful, as advised by Milojevic (2005), not just of future possibilities, but also to learn from historical investigations of influences (or resistance) leading to the rise or fall of innovations in education. At the outset of this paper we examined past experiences of the integration of technology in education, and this historical review revealed weak or ineffectual integration of technologies to date with only minor reforms within the education system. A recent report by the New Media Consortium calls for institutions to be "structured in ways that promote the exchange of fresh ideas, identify successful models within and outside of the campus, and reward teaching innovation" (Adams Becker et al., 2017, p. 2), and the advancements in new materials, augmented technologies and artificial intelligence highlighted within the three vignettes illustrate new ways to structure future learning experiences and learning environments to do just this. However, in doing so, there is a need as highlighted by Facer (2018) for the re-conceptualization of educational institutions not "as prefigurative spaces for the creation of better futures predetermined by adults but as laboratories and experimental spaces for children to explore the possibility of radical novelty" (p. 206). With respect to the latter, Facer (2018) offers inspiration in "preparing" teachers to work within the type of open learning spaces highlighted in the first vignette in the form of her innovative "pedagogy of the present" (p. 206), which involves five practices, namely, modelling, stewardship, reflexivity, disciplinarity, and experimentation, that seek to enable learners to critically envision and shape possible futures. Facer perceives that re-framing education around these five orientations might itself result in radically re-configured spaces that can support transitions within and beyond the school and its connected communities, as well as the creation of dedicated spaces such as: museum, farm or zoo (most likely embedded in communities) to facilitate experimentation of the world. The integration of smart materials and systems outlined in the first vignette within future school architecture would present real opportunities to explore these types of flexible learning spaces. Furthermore, the integration of augmented technologies and artificial intelligence as presented in the latter two vignettes would offer opportunities to explore the practice and impacts of Facer's "pedagogy of the present", by allowing learners to connect and collaborate seamlessly with each other and their teachers in real-time across virtual and physical settings, and to access, co-create and transform learning content and learning experiences in a myriad of authentic ways.

It is important to acknowledge the vulnerability of the developments highlighted within the vignettes to shifts and changes from a multitude of external factors including but not limited to environmental, economic, social, and political changes at local, national, and global levels. Beare and Slaughter (1993) remind us that when it comes to educational futures, far too often the preconceived notions of the system of education assumes the roles, policies, and institutions will remain a constant within the system when in reality, "the fundamental assumptions which govern our thinking about educational systems are themselves derived from a set of dominant, but often unexamined, assumptions about the nature of the world" (p. 4) and that it is not only possible, but permissible to reject the predicted inevitable future and visualize a world outside of the scope of industrialized vision of the future (Amsler & Facer, 2017). There is no doubt that schools will continue to be viewed as vehicles for solving economic and societal problems and in enabling transformation towards particular futures. Indeed, as Cuban (2004) notes:

> Deep-seated progressive and traditional beliefs about rearing children, classroom teaching and learning, and the values and knowledge that should be instilled in the next generation will continue to reappear because schools historically have been battlegrounds for solving national problems and working out differences in values (para. 20).

Therefore, a recurring challenge in futures studies research in education will be in revealing and challenging (dis)values and non-evidence-based policies that underpin dominant future planning for education, such as the need in any futures studies research exercise to challenge the neoliberal drive towards "preparing" learners for the knowledge economy that currently shapes much of what we do in education today. Hence, in our practice of futures studies research, we need to seek to engage in types of futures thinking that considers the potentiality of new technologies and materials in education within the bricolage of factors impacting on peoples, planet, peace and prosperity, and that considers learning opportunities across formal, non-formal and informal settings by reconnecting learning in schools with communities and families. Rittel and Webber (1973) state in their fourth property of wicked problems, "the full consequences cannot be appraised until the waves of repercussions have completely run out, and we have no way of tracing all the waves through all the affected lives ahead of time or within a limited time span" (p. 163). In the end we are embarking on unknown pathways trying to solve a truly wicked problem, that may be fraught with uncertainty, failed pathways, and many setbacks (Churchman, 1967; Rittel & Webber, 1973; Sardar, 2010), but through our actions to tame the wickedness of the problem we aspire to enhance the learning experience for everyone.

Funding

This research and work represented in this paper did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of interest

None.

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