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The Impact of AI on Curriculum Systems: Towards an Orbit-Shifting Dialogue

Title	The Impact of Artificial Intelligence (AI) on Curriculum Systems: Towards an Orbit-Shifting Dialogue
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Abstract:

"Orbit-shifting' refers to initiatives that seek to overcome obstacles to innovation, to maximize the impact of transformative change".

(Narang & Devaiah, 2014).

'*Artificial Intelligence'* (AI) refers to the theory and development of computer systems able to perform tasks normally requiring human intelligence. In order to achieve transformational change in contemporary curriculum systems and learning environments, we need to engender an orbit-shifting dialogue about the potential relationship between AI and education, in terms of both independent variables (threats), and dependent variables (opportunities). Through such a dialogue, we need to create foresight indicators that can predict the process of this relationship. It is, however, crucial that the relationship between AI and education is strong and directly proportionate. If the potential of the relationship is not exploited sufficiently, then under-developed education systems will lag behind and fail to achieve their potential for transformation, whether radical or incremental. Indeed, some may even become obsolete.

The paper contends that in order to effectively contribute to the knowledge economy and to sustainable development in the age of the 4th Industrial Revolution (characterized by a fusion of cyber-physical technologies) modern educational systems need to overcome obstacles to innovation in order to maximize the potential for transformative change. To achieve this will require an 'orbital shift' in educational planning, practice and resourcing, to enable schools to respond more effectively to the rapidly changing needs of young people, society, the economy and environment in the third decade of the 21st century. Schools, educational institutions and environments, need to transform from being primarily spaces for teaching and taking exams, into spaces for innovation and personal learning, based on a culture of actively listening to the voices, choices, needs and goals of learners. Teachers need to become facilitators, coaches and mentors for learners. Schools need to create AI-enabled, flexible, collaborative working spaces. Visionary, energetic educational leaders need to communicate effectively with all stakeholders, including employers and parents, to inspire and manage change and smart decision-making to develop schools of the future.

The aim of this reflection is to initiate an 'orbit-shifting' dialogue about the potential of AI applications to transform all components of the curriculum system to meet emergent 21st century educational goals. The conceptualization aims to explore the variable roles and impact of curriculum learning and assessment on these emerging educational goals. Theme 1 of the paper outlines the concepts and characteristics of a range of existing AI systems and their potential to enhance teaching learning and assessment. Theme 2 reflects on the potential to embrace AI systems across the curriculum system. Theme 3 proposes an action model to enable AI to have an 'orbit shifting impact' on all the components of the curriculum system (i.e. learners, teachers, learning environments, leadership and management, content, pedagogy and assessment) by enhancing opportunities for individualization, creativity and uniqueness.

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1. Introduction

'At the heart of every orbit-shifting innovation
is the breakthrough that achieves a transformative impact'

(Narang & Devaiah, 2014)

Research into artificial versus human intelligence has opened the door to *orbit-shifting* thinking and debate about the potential use of AI systems and applications across all types, forms and levels of education, which has major implications for curriculum, teaching, learning and assessment.

AI and human intelligence have much in common. AI software systems simulate human intellectual capabilities and may ultimately surpass them, in terms of the nature of their potential outcomes. For example, AI enhances learning by encouraging the use of previous and current experiences in new situations and scenarios, such as problem solving, thinking and reasoning, imagination and creativity. It employs visionary and sensory systems to predict the future, and uses experimentation and troubleshooting to detect errors and suggest alternatives to correct them.

AI software is already able to simulate human conversations. By 2020, it is likely that AI will be able to attend to 85% of communication with business customers. By 2025, the indications are that robots will replace 25% of the workforce and more than 60% of e-commerce businesses are expected to have incorporated AI into their platforms, responding to the transformational needs of international trade and emerging markets (Holmes, Bialik, & Fadel, 2019). With their capabilities to analyze performance, AI systems will provide the foresight to understand emerging developments and will improve scenario-based planning over the next decade and beyond.

United Nations' Development Programs are already using AI systems to achieve sustainable development goals and, more specifically, to try to address the many challenges related to poverty and starvation, by advancing healthcare, education, and environmental protection. Foresight indicators aim to ensure that investment in AI tools, software, and applications in different areas of business and education will continue to increase, so that human capabilities and material resources can be utilized more effectively.

AI: Threats, opportunities and challenges

Opposing perspectives regarding the future impact of advancements in AI software and technologies on the world of work persist. Optimists predict that AI will create new jobs and fields of business, while pessimists believe that AI will replace, and may eliminate, many jobs and areas of work. Few doubt that the increased adoption of AI systems will have an impact on employment processes and practices, particularly manual processes carried out by unskilled and semi-skilled workers. However, there is some evidence that AI may also create new opportunities to exploit resources more effectively. Accordingly, AI is both an independent variable (a threat) and a dependent variable (an opportunity) that affects, and in turn, is affected by, our current reality and prospective future. The challenge for every business is to understand, anticipate and plan for the independent variables or threats from AI and take maximum advantage of the dependent variables or opportunities it offers. The particular challenge for education is to understand the obstacles to innovation and to figure out mechanisms or action models to overcome those obstacles. That is the purpose of this paper.

Already the potential of AI is driving some educational and employment systems to think in terms of future learning outcomes, which, in turn, is influencing shifts in education, employment, and professional development requirements, courses and opportunities. The belief is that the incremental adoption of AI software and systems, both within and beyond education, is likely to increase the desire and opportunity to learn, while challenging current and future generations to find smart, innovative, and sustainable solutions to future challenges. Undoubtedly, AI will raise the bar in terms of the learning demands of current and future generations to develop life-long learning skills that make the greatest difference to levels of interpersonal, social, and professional capabilities. This presents both challenges and opportunities for educational stakeholders, especially those in charge of planning, designing, and developing curricula, which need to be kept under constant review and continuously updated to respond to emerging innovations.

Figure 1 (below) illustrates how the nature of work has changed over time in response to four industrial revolutions.

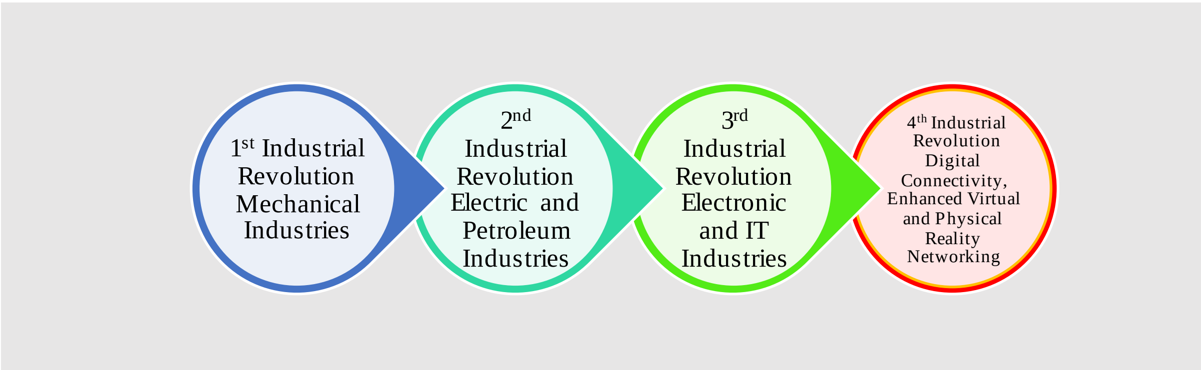

Figure 1: Stages of Evolution of Industrial Revolutions

The first, second and third industrial revolutions generated the need for human resources to serve industrial sector needs; hence, schools and curricula developed in a fairly linear fashion, to raise generations that could work in factories and offices. This mechanistic or utilitarian, conception of education focused primarily on producing workers to meet the needs of industrial economies as productive citizens. As the 21st century progresses, the world economic order continues to transition towards knowledge-based economies, in which there is a diminishing need for the type of industrial systems and processes that were prevalent in the 20th century, as automation is rapidly replacing manual processes. Evidence confirms that analytical and creative skills and capabilities are now increasingly in high demand. Despite the widespread acceptance that the skills that are easy to teach and assess in schools currently are now the least in demand in the job market (GEMS Education, 2016), nevertheless, educational models and systems in most countries are slow to adapt to the demands of knowledge-based economies for sustainable innovation.

There is evidence, however, in some educational systems that new patterns and models of curriculum and learning are emerging in response to economic change, technological advancement and global networking, and that these are playing a critical role in changing working environments. These shifts are indicators of the urgent need, not only to review educational practices around the world but also, to make a quantum leap in the nature and focus of educational systems and curriculum everywhere. The paper has three objectives:

1) To enable a clear understanding of contemporary AI applications, their concepts and characteristics;
2) To provide examples of how AI can enhance components of the curriculum system; and
3) To propose a model for developing the components of curriculum systems (i.e. learners, teachers, leadership and management, content, pedagogy and assessment) to enable 'orbit-shifting' educational transformation.

2: AI Applications – Concept and Characteristics

Types of AI applications can be categorized under three major headings: 1) machine learning, 2) artificial neural networks, and 3) cognitive analogies and data analytics (see table 1 below). Each of these can be divided into subcategories for research, learning, and application. For example, cognitive analogies have many sub-categories, including expert systems, smart programing languages, and learning and performance analytics. Similarly, machine learning includes intelligent agents, data mining, and robots, while artificial neural networks include knowledge representation, state space, and search algorithms.

Table 1: AI Applications – major categories and related sub-sets

1. Machine Learning	2. Artificial Neural networks	3. Cognitive Analogies & Data Analytics
Intelligent agents	*Knowledge representation*	*Expert systems*
Data mining	*State space*	*Smart programing languages*
Robots	*Search algorithms*	*Learning & performance analytics*

A brief description of the concept and characteristics of some of these applications follows, together with an analysis of their relevance and potential use in educational contexts.

i. Intelligent Agents and Machine Learning

An *intelligent agent* is a programmed entity that operates in a limited or open environment using sensors that derive some understanding of its surroundings by means of a set of consecutive processes and then modeling and configuring a set of variables and their possible impacts. When an Agent receives some form of sensory input from its environment, it then performs some actions that change its environment in some way. *Intelligent agents* have four main characteristics relating to environment, autonomy, adaptability and sociability. Its efficiency is measured by its reasoning capability.

Intelligent agents are used in some educational settings, for teaching languages, for example, or undertaking environmental analysis, science and math experiments, engineering education and educational games (Goodfellow, Bengio, & Courville, 2016; Zimmerman, 2018). They are beneficial to learning if the learning environment is designed to respond to multi-channel, multi-decision reactions. 'The intelligent tutoring system' for learning languages, for example, has four components as follows (abbreviated to *PEAS*):

1) A ***P***erformance measure, which assesses the learner's grade in the language test;
2) A Learning ***E***nvironment including a group of learners and a testing agent;
3) Learning ***A***ctuators, including e-learning spaces, exercises, trainings, activities and suggestions for improvements and corrections; and
4) Learning ***S***ensors, including smart interactive displays that observe potential reactions

ii. Artificial Neural Networks (ANNs)

Artificial neural networks (ANNs) attempt to simulate the networks of neurons that make up **a** human brain so that computers are able to learn things and make decisions in **a** humanlike manner. A human brain functions using millions of neurons, which in turn branch into millions of nerve endings. Knowledge perceived from the external world is stored in the brain. ANNs seek to simulate this by combining many processors in parallel to perform tasks in a similar way to the human brain. They process an infinite number of multi-scale results by drawing on recurrent and multi-layered neural networks and an array of different learning and backpropagation algorithms that require advanced modeling and training (Goldberg, 2017). ANNs can provide solutions and applications across many areas, including but not limited to, 'pattern recognition, weather prediction, handwriting recognition, face recognition, autopilot, robotics, etc' (Shururu, 2016).

ANN applications can be used in subject learning, for example to help with pattern recognition and image processing systems by creating a combination of patterns that help learners to more easily recognize and distinguish patterns. An example is organism recognition in biology. The network simulates the same process as a human being when learning by, for example, by comparing visual images of animals and their weights and storing this knowledge in computer memory. With repeated and diverse images, the network is able to learn and give correct answers without having to program complex written codes, as was previously the case with traditional applications.

iii. Expert Systems

Expert systems condense the knowledge, facts, and rules used by human experts to support non-experts to address difficult problems, such as medical diagnosis. They include:

1) *A Knowledge Base:* which differs from a database in that it contains intuitive, instinctive, and experimental knowledge including items, components, or variables specifically related to the problem to provide an expert 'working memory' (Merritt, 2017);
2) *An Inference System/Engine*: which is responsible for inference and reasoning, which follows the steps taken by an expert to address a problem by, for example, first testing the facts and rules of the system; adding new facts and rules as necessary; and defining the appropriate order of inference flow and user responses.
3) *A User Interface*: that interacts in an expert way with the knowledge base and the inference system.

Knowledge is represented according to the virtual or actual conditions for control, inference, and prediction. Representing knowledge in expert systems remains a challenging problem that requires more research. Some of the ways in which knowledge is represented are especially interesting, for example, mathematical logic, semantic network, frames, inheritance, and uncertainty, all of which can be used in education and learning to develop and enhance reasoning skills and semantic network thinking. This is particularly helpful in mathematics in light of mathematical evidence/logic, where knowledge is represented by semantic network approaches, which is one of the oldest approaches to representing knowledge as graphical representation, showing hierarchical relationship between objects, concepts or a series of events (Geron, 2017). The same applies to representing knowledge on nuclear fission.

Expert systems can support and enhance learning in, for example, physics, chemistry, geology, geography, and other disciplines that contain knowledge bases derived from lab experiments or from history or natural events. They are also used to support learning the basics of algebra, trigonometry, calculus, equations, linear proving, and non-linear branched proving.

iv. State Space and Search Algorithms

Within AI applications, the search for solutions follows a series of procedures, which use reasoning processes and search algorithms to search for values that match the required results. The general idea of a search algorithm is that it treats any problem as an input, and then provides solutions in a series of continuous events that searches for solutions within the 'State Space' to obtain a solution which can then branches into a continuous search and exploration towards an end goal.

State space and *search algorithms* are used in teaching and learning in a range of subjects such as history, geography, philosophy, psychology, environment studies, economics, and other areas of science and knowledge philosophies. A learner can build a tree of interrelationships that are based on paths (connectives) in a network of concepts and their meanings, going through lines of inquiry based on approaches and strategies, such as blind search, breadth-first search, depth-first search, bi-directional search, heuristic search, and best-first search strategies.

v. Genetic Algorithms

Genetic algorithms model problems according to the demographical and environmental characteristics of the population and accompanying entities, based on insights into genetic growth and development. They assume that a change in genetic characteristics occurs if, and when, a change occurs in the environment. This technology is based on coding genetic mutations (Holmes, Bialik, & Fadel, 2019), and analyzing every successive generation to explain how generational characteristics change. According to this application, a solution to a problem is dependent on analyzing the behavioral criteria of each generation and can suggest possible solutions to improve and develop such behavior, using demographic gene analysis. This application is to observe the development of the human race, to detect the factors that helped it adapt, change, or withdraw in similar or different environmental conditions, and to derive predictors of human behaviors associated with such conditions.

There is potential for *genetic algorithms* to be used in sociology, economics, ecology, biology, and the health sciences.

vi. Intelligent Tutoring and Coaching Systems

Intelligent Tutoring and Coaching Systems (ITCS) use a diverse set of computational technologies and interactions, which incorporate four essential software modules: a user interface, relevant content, an auto-tutor, and a learner module based on the theories and principles of cognitive and self-paced learning. It aims to provide instant personalized feedback to learners to enable and support constructive and effective learning.

There are many examples of the use of ITCS in both formal education and professional development. On-going research continues to improve its effectiveness in supporting self-tutoring in different contexts, including in class and online.

vii. The Internet of Things (IoT)

The Internet of Things refers to the ever-growing network of physical objects that feature an IP address to enable internet connectivity and communication between these objects and other Internet-enabled devices and systems, allow data to be analyzed and used innovatively. These are supported by wearable devices, like watches, accessories, glasses etc. some of which observe behavioral dynamics and interactions and/or provide augmented and virtual reality to allow users to experience the unseen world.

The growth and spread of small technology components that can be combined in interesting and creative ways has fed 'the Maker Movement' (learning by doing or 'making') and the creation of 'Makerspaces' (places where learners can gather to create, invent, tinker, explore and discover using a variety of tools and materials). The introduction of 'Makerspaces' in schools encourages teachers and learners to be creative, to act on their ideas, and to engage with design thinking (GEMS Education, 2016).

viii. Future Foresight and AI

Future foresight using AI involves the use of artificial intelligence applications to support the strategic analysis of processes and operating environments, combined with probabilistic (inductive, deductive and suggestive) reasoning, to improve understanding of the present and to consider emergent and future trends, based on the analysis of inputs, outputs and the potential impact of results. Future foresight cannot fully predict the future. Rather, its purpose is to identify trends, predict where significant disruptive change might emerge in the future, in order to make adjustments before change happens and/or prepare for the uncertainty that it may generate.

Educational institutions, like all other areas of human activity, need to engage in predictive analysis and put in place strategies to bring about necessary change in order to achieve sustainable improvement.

ix. Learning Analytics

Learning analytics refers to the measurement, collection, analysis and reporting of data about the progress of learners and the contexts in which learning takes place. Its purposes are to better track, support and optimize the performance of individual learners, by recommending approaches, strategies and resources customized to their unique learning abilities and needs.

AI applications and intelligent learning systems have already influenced the concept of learning and performance analytics. The effective use of *learning analytics* can empower teachers to better support learners, based on data interpretation, for example, by raising learning awareness, predicting the learning time needed for mastering a subject, providing effective feedback, suggesting customized pedagogical interventions, and improving the structure of learned and assessed knowledge (Swan, 2016). The concept of *learning analytics* is now commonly applied within many educational systems and a framework has been developed to make effective use of big data, while protecting the privacy of learner's performance data (Ebner, et al., 2015; Sclater, 2017).

Reflecting on this review of applications, it is short-sighted to think that the use and value of AI applications in learning and education is limited to accessing, organizing, sorting, and managing data to support decision making. The potential of AI extends far beyond this narrow conception and offers the opportunity to generate and build an extensive and integrated system of applications and interactions, which impact upon all components of the curriculum system, including teachers, learners, pedagogy, assessment, examinations, reporting, leading and managing schools, learning environments, accountability systems. It can also facilitate access to knowledge that promotes equality of learning opportunity and life-long learning, as well as enable the building of effective partnerships between schools and communities, locally and globally.

3: AI Applications in Learning and Pedagogy

Before reflecting further on AI's potential impact on the curricular system it is important to define what we mean by *'curriculum'*. Many definitions exist. Some take a human development perspective, viewing curriculum as a set of educational experiences, formally and informally delivered, to support the comprehensive growth and development of learners. Others take a more utilitarian educational perspective, seeing curriculum as a set of learning outcomes that learners should acquire throughout schooling. Going beyond these narrow conceptions, Tyler (1949) considered that any curriculum should be capable of answering four fundamental, questions relating to the 'why', 'what', and 'how' of learning, and 'how well' it delivers its purposes. Tyler also considered the curriculum should be kept under constant review and updated to meet changing learner needs and contexts, to ensure it continued to meet the purposes for which it was designed (ibid).

Given the scale and speed of the shifts towards a knowledge economy and the 4th Industrial Revolution, there is now a pressing need for curriculum frameworks to become more flexible, adaptable, and capable of fostering learners' capacity for personal learning, collaborative learning, self-learning and life-long learning in pursuit of equal opportunities, equality, justice and sustainable development. Accordingly, the following criteria expand on Tyler's four philosophical curriculum pillars relating to the 'why', 'what', 'how' and 'how well' of curricula to reflect a bigger picture /definition of curriculum that take account of contemporary and future learner needs and contexts. These include:

1. WHY: What a learner wants to achieve – (Personalized and relevant curriculum) goals;
2. WHAT: Sound epistemological and ontological foundations of learning, including explicit opportunities to bridge epistemological and ontological divisions to maximize relevant multi-disciplinary and trans-disciplinary learning and problem-solving – (i.e. a flexible, connected curriculum);
3. HOW: Learning spaces, activities and communications, enhanced by AI as appropriate, that foster collaborative learning – (an experience-based, pedagogically-engaging curriculum);
4. HOW WELL: Tutoring, mentoring, advice, and orientation mechanisms that monitor, support and enhance learning – (a well-resourced and supported curriculum); and
5. HOW WELL: Differentiated criteria to assess and evaluate the curriculum – (a customized and continuously refined curriculum).

The review and revision of curriculum to take account of these five drivers will enable the curriculum system to development roles, competences, and expectations to meet the changing needs of learners as we become immersed in the 4th Industrial Revolution. Meeting these needs is the focus of the change management model now proposed in this paper. However, without a plan for transformative pedagogical design, smart technology will remain ancillary to personalized learning (Abdelaziz, 2019).

In response to the increased deployment of AI applications across education, a range of innovations, tools, frameworks, and approaches are emerging, that make the best of AI in teaching, learning and assessment. Over the past two decades, aspects of AI have stimulated the development of pedagogical inventions, tools and practices that are having a positive impact on learning situations (Ferguson, 2017; Sharples, 2012, 2014). The following indicative examples represent, in form and in substance, the potential comprehensive and 'orbit-shifting' impact of AI on the curricular system. Table 2 summarizes these shifts.

Table 2: Emerging Pedagogical Trends 2012-2017

	Pedagogical Innovations 2012 (Sharples et. al., 2012)	**Pedagogical Innovations 2014** (Sharples, et. al., 2014)	**Pedagogical Innovations 2017** (Ferguson et. al.,, 2017)
1	Innovative ways for teaching and learning through 2nd generation e-books.	Free, open-resource e-courses based on social collaborative learning.	Building long-term collective memory in minutes using??.
2	Producing and publishing professional development and entertaining short courses.	Published electronic tools linking design to analysis of effective learning.	Learning analytics and producing science and knowledge.
3	A shift from judgmental assessment to developmental dynamic assessment for learning	Blended learning modes inside and outside classrooms.	Licensing learning products with Creative Commons licenses through OERs.
4	Learning badges as a framework for open learning to gain professional skills and capabilities.	Pedagogical engineer and management	Building learning augmented reality communities to enhance knowledge integration.
5	Massive Open Online Courses.	Learning by design	Learn with others using e-collaboration.
6	New forms of knowledge generation and distribution through Social learning platforms	Personal developmental assessment to enhance learning.	Learning based on design thinking and authoring tools
7	Seamless learning with systematic connection between context, technology, and learning activities.	3D time-bound, hierarchical learning events.	A shift from lagging to leading learning indicator and performance
8	Learning Analytics.	Predictive analytics and learning paths	Big-data inquiry and data-based learning.
9	Online Collaborative Learning and Inquiry	Dual-impact differentiated learning through active research.	Self-esteem and self-interest learning.
10	Immersive learning design	Deep learning through impact-based assessment	Learning for unique future power. Learning for inclusive growth

Interaction between the smart technologies and pedagogical trends outlined in Table 2 (above) align well with the drive to create *Innovative Learning Environments* proposed by the Organization for Economic Co-operation and Development (OECD) in 2013. These recommended:

1. Placing learners and sustainable development goals at the center of learning;
2. Making learning and engagement the central role of modern schools;
3. Enhancing and sustaining social and collaborative learning as a major component of contemporary curricula;
4. Enhancing learner motivation and paying attention to the importance of emotions (harmonizing the drivers, goals, and emotions of learners).
5. Paying greater attention to individual differences in learning style, including pre-existing knowledge and cultural backgrounds;
6. Closely following up on learner progress as a constant focus;
7. Designing assessment to support learning goals, with a strong emphasis on formative feedback; and
8. Encouraging connections between learning activities

Access to smart AI technologies (enhanced by augmented reality tools, software, and applications) will generate the kinds of learner-centered engagement, and, social emotional and collaborative learning, envisaged in the first four drivers. What is needed to maximize the impact of AI is the use of pedagogical strategies that pay greater attention to individual learner differences and their progress in learning alongside formative assessment and feedback that encourages learners to make connections across their learning activities. To achieve this requires an action model for developing all components of the curriculum system - (i.e. learners, teachers, leadership and management, content, pedagogy and assessment, (see Figure over).

Building on the insights outlined in

2: AI Applications – Concept and Characteristics (AI systems) and

3**: AI Applications in Learning and** (pedagogical processes), the model proposed here for enhancing the developing all components of the curriculum system is based on a further set of transformative educational goals considered essential to meeting the needs of learners in the age of the 4th Industrial Revolution, (Abdelaziz, 2019): These include:

- Building viable models and patterns to enhance personal learning;
- Enabling learners to develop design thinking and creative problem solving skills;
- Creating and promoting a culture of creativity and innovation within engaging learning contexts and environments;
- Enhancing differentiated learning, and developing learners' self-regulation skills;
- Developing a growth mindset (Dweck, 2007) amongst teachers, learners, and school leaders;
- Embracing ontological divisions of scientific concepts, learning analytics, and emerging and evolving pedagogical contexts.

4: An Action Model to transform the impact of AI on the curriculum system

The following brief descriptions use foresight trends to envisage the future characteristics of each of the seven components of the curriculum system in the age of the 4th Industrial Revolution. The descriptions reflect how the components are enhanced by the use of AI technologies and how this is likely to increase in the future, particularly in progressive education systems. The descriptions are used to create a procedural framework that draws on new visions, philosophies, and emerging pedagogical inventions to envisage a systematic orbital-shift in the form and substance of international curricula to achieve emerging educational goals.

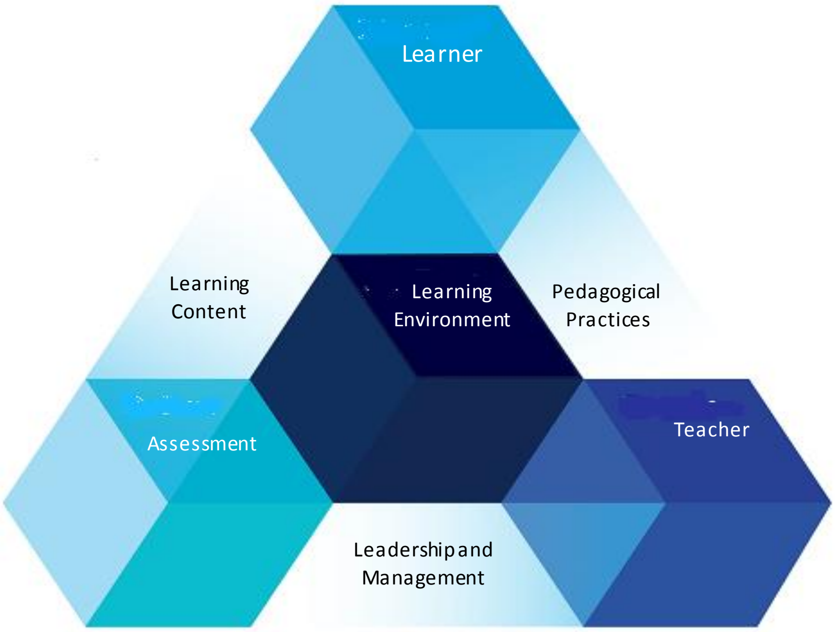

Figure 2: Components of the Curriculum System

Key characteristics of the components of the curriculum system using foresight potential

Characteristics of 4th IR Learners

Learners in the 4th Industrial Revolution are more intuitively curious about their surrounding world; they are passionate to acquire, exchange, and share knowledge using tools, technologies, social networks and information exchange forums. 4th IR Learners are also dynamic; they have developed growth mindsets, individual desires and learning preferences. These characteristics demand that we, as educators, use AI applications to enable and map personalized learning that responds to the voice, respects the choices, and caters for the needs of learners, while promoting their motivation, engagement and immersion in learning, and enhancing self-efficacy, self-organization and ownership of their own learning. (Bray & McClaskey, 2015; 2017).

4th IR Teachers

Teachers in the 4th Industrial Revolution possess unique pedagogical capabilities to customize content to different learning capabilities, and to design learning relationships and partnerships with innovative providers to enhance self-development (Prince and Jason, 2015). In addition, 4th IR teachers participate in international professional networks to strengthen their capacity to guide their learners in response to insights from AI learning analytics. Such applications enhance opportunities for learner independence, innovation and continuous experimentation. Using these applications, teachers develop their own personal learning plans to enhance their professional performance. Teachers in the 4th IR have transitioned from traditional class teaching to become mentors and consultants, facilitators and coaches of learning as well as embracing other leadership roles. The role of teachers in the age of the 4th Industrial Revolution has therefore been reframed to include: the design of professional growth tracks; monitoring the development of learning contexts; developing individual performance; managing innovative portfolios in school linked to society; organizing and analyzing data based on systems and algorithms and cognitive analogies incorporating pedagogical analytics.

4th IR Assessment

Assessment in the 4th IR generates is better designed and targeted as a consequence of the increased use of AI technologies and applications. The assessment process as a result, has become more dynamic, adaptive and differentiated, drawing on learning analytics, personal performance algorithms, expert systems, acquired and practiced cognitive analogies and maps that enhance evidence-based learning, and impact-based assessment. Tailored assessment processes generate more insightful analytical data, based on evidence, which provide learners with personalized feedback. Practices relating to the performance management of learners, teachers and the whole school system focus, not only on expected learning outcomes but also, on analyzing personal attributes and learning dispositions, such as self-efficacy, motivation, skills, attitudes and values, and areas for development. Assessment practice has transformed from assessment *of* learning into assessment *for* learning, assessment *as* learning, and assessment *in* learning. Learners, supported by teacher mentors, build their own personalized learner profiles, learning portfolios and learning plans that guide individual learning cycles, which generate personalized feedback and guidance on how to progress in learning both cognitively, socially and emotionally.

4th IR Learning Environments

Learning environments in the 4th Industrial Revolution are no longer limited to the classroom environment and the dynamics inside schools. Learning environments now span multi-purpose learning spaces with flexible, adaptable, mobile, and individualized infrastructures, both real and virtual. AI-advanced learning environments provide a wide range of choice, activities, resources, tools, platforms, within collaborative and personalized learning spaces. Learners have access to laboratories, virtual experiments, 3D models, augmented-reality-based tools and software, smart learning agents, materials and systems, machine learning, and the Internet of Things that, collectively, support learners to explore and interact with a wide variety of knowledge sources. These enable learners to build personal learning spaces and networks, in which teachers consult with, observe, monitor and mentor learners in real and virtual spaces. Learners are enabled to research, manage, share, publish, and distribute the innovative outcomes of their own learning, as opposed to memorizing, recalling and reciting knowledge for summative exams. Technological components and electronic wearable devices drive the 'Maker Movement' do-it-yourself making and tinkering, involving everything from electronics, robotics, metal and woodworking, and other pursuits. School 'Makerspaces' enhance design thinking and collective innovation, using 3D printers to create prototypes. Learners exploit their own devices (BYOD) to create, make publish and share their own content (CYOC).

4th IR Learning Content

Advances in AI technologies and applications enhance opportunities for learners to engage with diverse, differentiated, adaptable, customized and personalized content, according to the choices and needs of learners. Despite the diversification of learning technology, and its increased use in learning, teaching and assessment, maintaining content relevance remains a challenge in the 4th IR.

Alongside the development of critical, creative and caring thinking, relevant and reliable content remains the ontological and epistemological structure that needs to be mastered by learners to build the foundations for cognitive development and progression. Organizing and upgrading learning content remains a challenge for educators, especially with the role that social networks continue to play in publishing, distributing, and exchanging knowledge, which may be of questionable veracity.

AI technologies and applications offer many alternative approaches and opportunities for learners to access, review, organize, create, publish, and distribute content, using expert systems, machine learning, cognitive analogies, search algorithms, and inquiry and reasoning to enhance the veracity of their outcomes. However, the educational challenge lies in developing learner skills to access, manage and analyze the veracity of information, to reduce learner misconceptions and misuse of information derived from internet sources. A philosophical approach, based on the 'cycle of certainty', has value as a learning strategy for understanding and differentiating between:

- Declarative Knowledge - the knowledge of certainty (the What?): like facts, symbols, definitions;
- Procedural Knowledge - the eye of certainty (the How?): like procedures, algorithms, performances;
- Connective Knowledge – the truth of certainty (the Why?): like generalizations, suggestive reasoning, conclusions; and
- Conditional knowledge – the complete certainty (the What If? What's Next?): like synthesis, plans, and mental conceptualizations.

Learners require support to progress vertically and horizontally, through immersion and engagement, to represent knowledge, build meaning, and develop semantic and ontological understanding. Most of all, however, they need to develop the capacity for critical, creative and caring thinking and personal reflection.

4th IR Pedagogical principles

4th IR and AI-enhanced pedagogical practices focus on the following principles that impact teaching and assessment practices and systems (Abdelaziz, 2019):

1. Re-engineer the role of teachers to become curriculum designers and facilitators, coaches, and mentors of learners and learning;
2. Design relevant curricula in response to deep reflection on the why, what, how and how well challenges of the 4th IR;
3. Analyze individual learner's cognitive and emotional dispositions, to inform the design of differentiated learning opportunities and more flexible learner choices;
4. Provide flexible and differentiated learning opportunities that enhance learners' strengths, identify shortcomings and offer supportive feedback;
5. Facilitate productive and developmental dialogue to build scientific conceptions and represent conceptual knowledge of principles and theories within and across disciplines;
6. Employ pedagogical practices that offer choice, enhance learner engagement, immersion and interaction with digital and non-digital content, using skilled facilitation, coaching and mentoring (the wisdom of practice, Shulman, 2007);
7. Use cognitive, emotional scaffolds to enhance learning behaviors and interactions;
8. Use interactive pedagogy to nurture the development of:
    a. cognitive understanding of the components and characteristics of knowledge and the construction of meaning;
    b. Strong and deep knowledge, collective cognition, and individual and collective self-efficacy;
    c. Creative problem solving, design thinking, authoring, exchanging, distributing, and publishing knowledge;
    d. Growth mindsets that take risks for learning, persist in the face of frustration, learn from failure and sustain effort and resilience in their search for solutions;

9. Embrace the opportunities provided by AI, for learners: to learn from experts; to learn from others; to learn by doing; to engage in exploratory learning; inquiry learning; to learn within collaborative and personalized learning spaces; to learn from 360 degree of feedback and feedforward; to engage in loop learning; to; learning through smart agents; etc.
10. Embrace the opportunities provided by AI to enhance the focus and quality of assessment and feedback on strengths and areas for development; to provide data to analyze progression, stagnation and/or regression; to inform self and peer assessment and advice of next steps in learning; and for teachers to analyze the impact of their teaching and refine as necessary.

Enacting these principles, supported by AI applications and tools that take account of learners' needs, choices, learning motivations, and goals, has the potential to profoundly alter curriculum, teaching, learning and assessment in the 4th IR and, to render traditional practices obsolete.

4th IR Leadership and Management

It is a mistake to think that the low budgets allocated to education is the main cause of poor educational performance across educational systems. There is little doubt that educational leadership has a substantial contribution to make in improving current and future curriculum systems. Leadership armed with a progressive vision, a positive mission, a good understanding of AI systems and their potential impact and strategic actions to engage with AI, can bring about major shifts in attitudes and practice.

It is already the case that, AI applications, specifically those based on learning, pedagogical, and analytic approaches, can enhance leadership capacity and individual and collective performance at the school level, as well as communications with staff, students, parents, employers, and others benefiting from learning results and outcomes. In both the short and the longer term AI applications can transform leadership and management systems from top to bottom, allowing greater space for management innovation, the distribution and delegation of roles and responsibilities, and greater flexibility indecision-making, taking advantage of 360 degree feedback and feedforward. For example, systems like remote sensing, cognitive analogies, and cloud computing applications, offer spaces for collaborative innovation that encourages active listening and inquiry, a culture of trust and the encouragement to build learning communities and practice-based leaderships. AI-based decision-making systems can also provide innovative spaces to manage day-to-day schedules, long-term planning, and material and non-material school resources, including human resources leading to greater benefits from support and accountability systems. Overall, AI applications and smart systems for decision-making will change and improve educational leadership and drive change across other components of the curricular system, creating time, space and resources that will enable innovative conversations and engagement, and forward planning. All these inputs will accelerate a transformation from management preoccupations, which currently focus on processes, into educational leadership, which focus on self-management, collaborative engagement with others, empathy, mentoring and leaders as change agents.

Action model

The essence of innovation is making familiar of the unfamiliar / the unfamiliar familiar. The following model aims to support incremental change in current practice, paving the way for sustainable innovation in the curriculum system in the age of the 4th Industrial Revolution. The purpose of the model is to help users and beneficiaries to think tetragonally (in four dimensions) about the potential for multiple impacts and interactions that might arise from particular innovations. Each component of the curriculum system is a potential agent for change and innovation and has potential to generate an orbit shifting dialogue, about whether or not to abandon, embrace, adopt, and/or elaborate on innovative opportunities. Figure 3 simplifies these considerations into a process of continuous interaction.

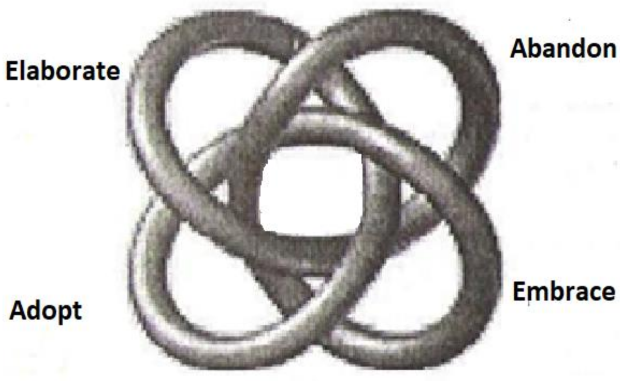

Figure 3: Action Model - Quadraple Impact Orbit Shifting Dialogue

For example, when a traditional concept or practice, there is a need to embrace, adopt, and elaborate new or alternative practices, concepts and/or applications that can drive change until the traditional practice becomes obsolete. Then a new cycle of 'abandon, embrace, adopt, and elaborate' begins with new and emerging concepts and practices, and so on. Table (over) illustrates some of the orbital shifts in practice that may ensue from embracing AI applications across each of the components of the curriculum system (i.e. learners, teachers, learning environments, leadership and management, content, pedagogy and assessment).

Table 3: Orbit- Shifting Affecting Components of the Curriculum System

	Components of Curriculum System	**Rings of Change towards Orbit-shifting practice**			
		Abandon	**Embrace**	**Adopt**	**Elaborate**
1	Learners	Memorizing and Recalling	Engagement	Ownership	Personalization
2	Teachers	Teaching	Facilitating	Coaching	Consulting and customizing
3	Learning Environment	Linear/ Random	Adaptive	Dynamic Active Inquiry Spaces	Collective and Collaborative Spaces
4	Assessments	Assessment of Learning	Assessment for Learning	Assessment as Learning	Assessment in Learning
5	Learning Content	Universal	Intensive and Focused	Targeted	Adaptive/ Customized and Connected
6	Pedagogies	Lecturing	Pedagogical Intervention	Pedagogical Engineering	Pedagogical Analytics
7	Leadership and Management	Process Leadership	Corrective Leadership	Innovative Leadership	Transformative Leadership

5: Conclusions and Recommendations

Conclusions

"Orbit-shifting' refers to initiatives that seek to overcome obstacles to innovation, to maximize the impact of transformative change". (Narang & Devaiah, 2014). This reflection argues that, to contribute effectively to the 21st century knowledge economy and the principles and directions of sustainable development, curriculum systems need to make use of AI applications to maximize the potential to bring about an orbital transformation in educational practice. The action model calls for educational leaders to abandon consumable technologies and adopt smart applications that can make a radical difference to current and future practice, that allow wider space for individualization, uniqueness and wellbeing.

Schools need to embrace smart, sustainable, future-sighted AI systems that can help to transform classrooms into spaces for innovation and personal learning, based on a culture of actively listening to the voices, and attending to the choices, real needs, and future goals of learners. Schools need teachers, who can facilitate, coach and mentors learners within collaborative learning environments. Leaders need to communicate with and engage all stakeholders, including employers and parents, in smart decision-making.

Recommendations

The following strategic recommendations highlight a range of strategic actions necessary to support the dynamic transformation of educational and curriculum systems in the effective implementation of appropriate AI systems:

1. Build AI teams within ministries of education, school support bodies and higher education to develop foresight thinking, plans and policies to enhance all components of the curriculum system at schools, further and higher education levels.

2. Allocate adequate resources to enhance the future of learning in schools and universities alike, using future foresight to develop potential scenarios for the form and substance of schools in the future.

3. Plan, design, and carry out initiatives, programs, and workshops to raise awareness of AI software and applications, targeting schools, universities, and local communities.

4. Build sustainable community partnerships with employers, parents, NPOs, NGOs to provide the social and logistic support necessary to build trust in the outcomes of AI enhanced curriculum systems.

5. Form international partnerships to develop specialized smart pedagogical labs in schools, to develop the necessary scientific research, models, capabilities, and human resources to expand the uptake and application of AI and smart learning systems internationally.

6. Redesign school learning environments to offer personal learning within sustainable innovation spaces, to transform learning from a culture of recall and memorization to a

culture of collaborative engagement, design thinking, cognitive analogies, and digital/smart learning.

7. Use the action model illustrated in this paper as a framework to develop and enable teachers, who are the main component of the curricular system, to develop appropriate pedagogies, and to model AI applications in learning situations.

8. Support leaders, teachers and learners to develop the competences (knowledge, skills, attitudes, values and actions) to embrace and successfully navigate the challenges that the 4th IR will undoubtedly present.

'At the heart of every orbit-shifting innovation is the breakthrough that can achieve transformative impact' (Narang & Devaiah 2014). This reflection considers that the adoption of AI across the curriculum system is the breakthrough that can bring about *'orbit-shifting'* innovation within education, to maximize the impact of transformative change. I rest my case.

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