DIGITAL TECHNOLOGY AND EDUCATION IN THE ERA OF INDUSTRIAL REVOLUTION 4.0

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By:
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0. Introduction

This short paper is structured to spur us in adopting development in particular so that we are in sync with the development guidelines of our country and the world in the Industrial Revolution 4.0 era, and as our initial thinking in designing education that is definitely changing, following the development of digital technology. Lecturers/teachers, economists, business people, officials, politicians - in lectures, directions, remarks, speeches, releases, policy statements - expressing about the Industrial Revolution 4.0 (briefly RevIn-4) and digital technology. What exactly is RevIn-4? What is the connection with disruption that is also being talked about? What is meant by millennial generation? What is the impact of RevIn 4.0 for Schools/Universities and lecturers/teachers? These are among other things our concern today that will be elaborated in this paper.

The next presentation will focus more on the review of aspects of Connectivity, Digital Technology and the Internet, as well as anticipation relating to the advancement of digital technology that is now affecting human life. Physical Cyber System (CPS), which has now penetrated human life, is closely related to Artificial Intelligence (AI) and pervasive computing (ubiquity) and RFID (Radio Frequency Identification) which now penetrate human life has felt its impact in the form of "disruption". The paper also elaborated on the human generation as related to the advancement of technology, especially millennial generation which is the object of learning in educational institutions in the digital era.

So, the keywords used for this paper are:

@ digital technology
@ algorithm
@ connectivity and internet
@ disrupsi-4 or industrial revolution 4.0
@ CPS - Physical Cyber System
@ millennial generation

1. Digital technology

The application of IT as part of economic digitalization, digitizing administration and administering education (e-learning) has now begun to develop throughout the world, including in Indonesia. It's no doubt if we have now changed from an "analog" world to a computerized "digital" world. Our daily activities also has adjusted to digital ways such as paying in toll roads, administration and tax payments , money transfers through mobile and

sms banking etc.. Similarly, the last few years some of us in our social activities and communications are difficult to separate from digital social media such as Whatsapps, Line, FB etc.

Figure 1. Analog vs. Digital

Figure 1 provides a visualization of the differences between Analog and Digital. Both of these technologies, although giving similar results, each have very basic differences. Sound recordings stored on a tape (tape recorder) are examples of analog technology while recording on a computer or cellphone in the form of files is digital technology. It is said, that analog data is continuous, while digital data is discrete. The analog signal intensity can go up and down, while digital remains, using 0 and 1 digits (yes, no or 0, 1). From the row of values or the number "0 1" this appears the digital term (digit = number, finger).

The internet is a means of communication with mobile phones and computers (laptops, desktops, etc.) which are all digitally based. Likewise with cameras, most watches, GPS, etc. - everything is all digital.

2. Algorithm

The Algorithm (Alkwairizmi or Alkawarizmi, 780 - 850 AD) was a mathematician in the era of Abdurrakhman II, sultanate in Cordoba (now Spain), one of the mathematical developers, especially Algebra. From the name we know the term algorithm. Speaking of computers, we cannot be separated from the term algorithm. In computer programming algorithms are used in the form of a series of procedures and instructions and with algorithms can be compiled computer programs, among others for AI (Artificial Intelligence) and big data utilization for various purposes in digital technology. A little is said here about who is Alwairizmi or Algorithm. According to historian al-Tabari, the full name of Alkawarizmi is Muhammad ibn Musa al-Khwārizmī al-Majousi al-Katarbali -محمد بن موسى الخوارزميّ المجوسيّ القطربّليّ) - indicates that al-Khawārizmī is from Qutrubbull, near Baghdad (now Iraq). Alkwairizmi wrote many scientific books, a.o. two main works: 1/ Algebra - Al-Kitāb al-mukhtaṣar f.ī. ḥisāb al-jabr wa-l-muqābala - الكتاب المختصر في حساب الجبر والمقابلة - Book that summarizes the definitions of Algebra, and 2/ Arithmetic - Kitab al-Jam'a wa-l-tafrīq bi-ḥisāb al-Hind (Book of Hisab Science based on Hindu Calculations) - also popularly known as Dixit Algorizmi. (Wikipedia).

3. Connectivity and the Internet

The existence of a computer has triggered connectivity more smoothly and broadly. Connectivity is a basic infrastructure in human life. With connectivity we can communicate with each other. Metcalfe's law states that the value of the telecommunications network (k) is proportional to the square of the number of users connected in the system (n^2). Exactly, not n^2 but n (n - 1) / 2. Two objects (such as telephones) have one connection, five objects have 10 connections.

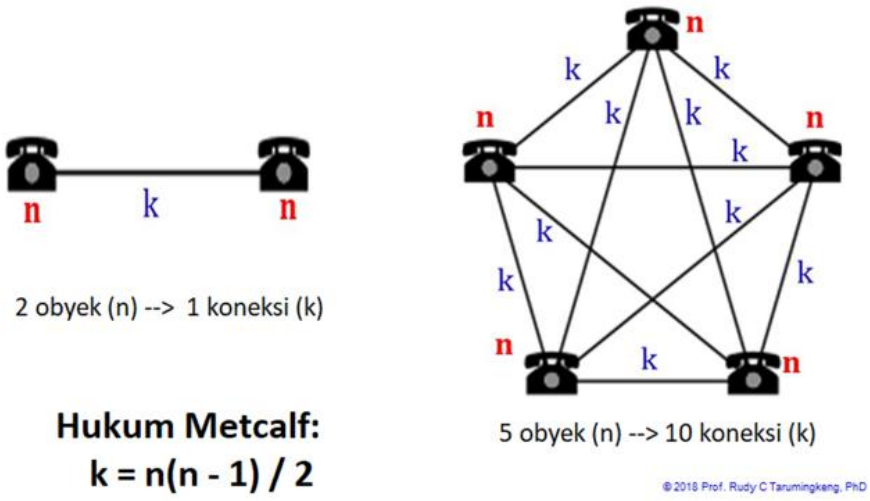

Figure 2. Metcalfe's Law: k = n (n - 1) / 2

If we have 12 phones (n) it can be formed n (n - 1) / 2 = 12 (12 - 1) / 2 = 66 connections. Imagine if all the world population would be connected, how many trillion connections would be needed? The development of communication with the advancement of IT (Information Technology) takes place in line with Electronics and Digital Technology

innovations. In 1965 electronics expert Gordon Moore, founder of Fairchild and Intel predicted that the number of transistors that could be combined in an integrated circuit (IC) had doubled every year. It is predicted that this acceleration will last until around 2013 and will reach saturation in 2015. In 2018 it turns out that the development of digital technology continues to progress even more accelerated with various innovations and inventions. Especially with the development of Artificial Intelligence (AI), nanotechnology and advanced materials science (including memory technology - which evolved from silicon to germanium).

The reality shows that the development of computer technology, communication and information tend to run exponentially, while human ability to adapt to this progress tends to be linear. Therefore, the development of the internet, computers and smartphones takes place so fast that humans and their communities tend to be slow to adapt them. Likewise, government tends to be late in setting up regulations related to digitalization because of the rapid development of digital technology.

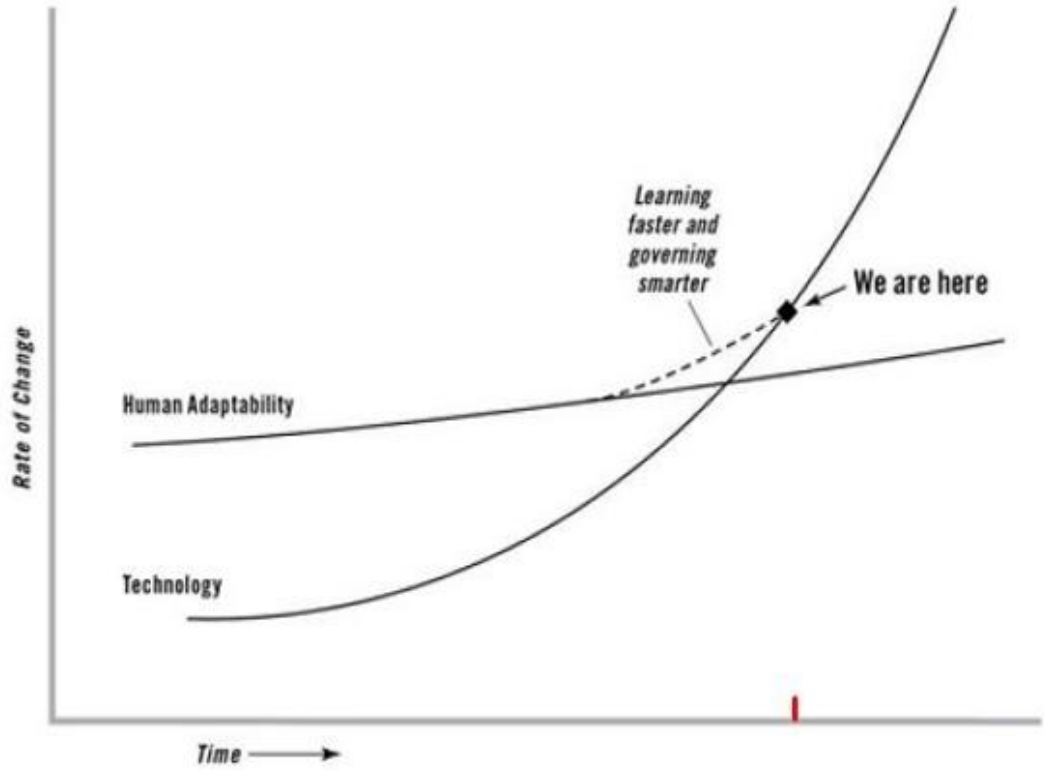

Figure 3. Acceleration of technological growth *vs.* growth of human adaptation to technology

Technology increases exponentially but the growth of human adaptation to technology is only linear. This is analogous to Malthus's law of population growth vs. food supply growth. We need to accelerate technology adaptation so that it doesn't fall behind (Friedman 2016)

Figure 3 above shows the acceleration of technological progress that is exponential (very fast), but people or society is still slow to adapt to the advancement of technology. The growth of this adaptation although uphill, only lasts linear. Friedman (2016) argues that efforts are needed so that the community is smarter in understanding and absorbing digital technology so that the crisis of disruption is not too straightforward. Internet (Inter - inter; Net - communication network) is a world connectivity network that is interconnected. Internet development began in 1969, with the advent of APRAnet. The internet began to become popular in 1989 with the development of the WWW (Worldwide Web) and HTML (Hypertext Markup Language). Internet use in business and commerce began in 1991 even though the operating system was still very limited. The first Mosaic browser, Netscape was only developed in 1993 at the University of Illinois, and began to be used in general in 1994. The browser that we use today (IE, Google Chrome, Mozilla) only emerged later in the 1990s and 2000s. Dell, Cisco and Amazon.com began using the internet for commercial transactions in 1995. Furthermore, the deregulation of the government in the telecommunications sector and various innovations has helped the rapid development of the internet and digital telecommunications.

List 1 below shows that internet users (cellphones & computers) in Indonesia are ranked number 5 in the world and have experienced an increase of around 7% from the previous year. Of the total population of 266.8 million, more than half, 143.3 million (53.7%) have used the internet with computers and smartphones. This data shows that we are slightly in the world average (50.1%). Even though our current position is above average, the use of the internet for education is still very lacking.

TOP 20 COUNTRIES WITH HIGHEST NUMBER OF INTERNET USERS - DECEMBER 31, 2017

#	Country or Region	Population, 2018 Est.	Population 2000 Est.	Internet Users 31 Dec 2017	Internet Users 31 Dec 2000	Internet Growth
1	China	1,415,045,928	1,283,198,970	772,000,000	22,500,000	3,331 %
2	India	1,354,051,854	1,053,050,912	462,124,989	5,000,000	9,142 %
3	United States	326,766,748	281,982,778	312,322,257	95,354,000	227 %
4	Brazil	210,867,954	175,287,587	149,057,635	5,000,000	2,881 %
5	Indonesia	266,794,980	211,540,429	143,260,000	2,000,000	7,063 %
6	Japan	127,185,332	127,533,934	118,626,672	47,080,000	152 %
7	Russia	143,964,709	146,396,514	109,552,842	3,100,000	3,434 %
8	Nigeria	195,875,237	122,352,009	98,391,456	200,000	49,095 %
9	Mexico	130,759,074	101,719,673	85,000,000	2,712,400	3,033 %
10	Bangladesh	166,368,149	131,581,243	80,483,000	100,000	80,383 %
11	Germany	82,293,457	81,487,757	79,127,551	24,000,000	229 %
12	Philippines	106,512,074	77,991,569	67,000,000	2,000,000	3,250 %
13	Vietnam	96,491,146	80,285,562	64,000,000	200,000	31,900 %
14	United Kingdom	66,573,504	58,950,848	63,061,419	15,400,000	309 %
15	France	65,233,271	59,608,201	60,421,689	8,500,000	610 %
16	Thailand	69,183,173	62,958,021	57,000,000	2,300,000	2,378 %
17	Iran	82,011,735	66,131,854	56,700,000	250,000	22,580 %
18	Turkey	81,916,871	63,240,121	56,000,000	2,000,000	2,700 %
19	Italy	59,290,969	57,293,721	54,798,299	13,200,000	315 %
20	Egypt	99,375,741	69,905,988	48,211,493	450,000	10,613 %
TOP 20 Countries		5,146,561,906	4,312,497,691	2,937,139,302	251,346,400	1,068 %
Rest of the World		2,488,196,522	1,832,509,298	1,219,792,838	109,639,092	1,012 %
Total World		7,634,758,428	6,145,006,989	4,156,932,140	360,985,492	1,051 %

NOTES: (1) Top 20 Internet Countries Statistics were updated in December 31, 2017. (2) Growth percentage represents the increase in the number of Internet users between the years 2000 and 2017. (3) The most recent user information comes from data published by Facebook, International Telecommunications Union, official country telecom reports, and other trustworthy research sources. (4) Data from this site may be cited, giving the due credit and establishing a link back to www.internetworldstats.com.

List 1. Twenty countries ranked the world's top internet users (December 2017).
Source: http://www.internetworldstats.com/top20.htm -vis. June 2018)

4. Disruption / Industrial Revolution 4.0

We have all heard about what is disrupted. Literally, disruption means "interference". Any disturbance in the paradigm of human life can be good or bad. A process that experiences disruption can result in a decline or even the cessation of the process. But many disruptions also bring improvements, acceleration, improvement of a process, resulting in extraordinary performance. Improvements can take place if disruption occurs as a result of human efforts to improve technology in order to increase the benefit for human life. In the process of mankind all the time, various disruptions have occurred, for example world wars, economic crises and disruptions that we are now experiencing and become a major concern in the development process, namely disruption due to changes in industrial technology systems. This change in the technology system is our main focus. All of this is inseparable from the discovery of computers which are then widely used in industry and human life in general which have provided many conveniences and efficiencies in human life.

Throughout prehistory and world history there have been various technological revolutions that have changed the way of life and human culture. Before the era of history, known as the pre-historical era, which began at the beginning of the stone age around 2

million years ago, which continued with the Bronze Age around 5 thousand years ago; then came the iron age about 3,000 years ago. This continues with the historical era which began around 1500 BC which is also known as the era of human development to the modern era today. It can be said that the disruption that occurs now starts from the development of digital technology related to the development of computers, information technology, the internet (connectivity, communication) and artificial intelligence (AI). This phenomenon has changed many of the economic and social processes of human life that gave rise to the digital economy (e-economy), social media, RFID, pervasive computing. With computer-based digital human intelligence, it will be easier to control many things such as disease diagnosis, forecasting and controlling the climate and environment, manufacturing, trade, education, and many things that humans do can be replaced by digitally controlled machines.

Pervasive computing technology is connectivity that takes place anywhere and between objects / humans and other objects - which are currently developing. This connectivity / identification is automatic without requiring a cable connection and is called RFID (Radio Frequency Identification). RFID is an identification system that has now been used to enable data retrieval without having to touch or require barcodes and magnetic cards such as ATMs.

The first wave of computer technology that took place since before 1990 was the Mainframe Computing era. This is because the technology at that time did not develop as it is now - so a large computer is used together through workstations. The next wave was the era of PC (Personal Computer), the size of a computer became smaller (but its ability exceeds the Mainframe computer so that it functions as a personal computer that we usually call desktop. This era still continues today but with innovations in nanotechnology so that its development extends to smaller size computer and portables like laptops, smartphones, tablets, etc.

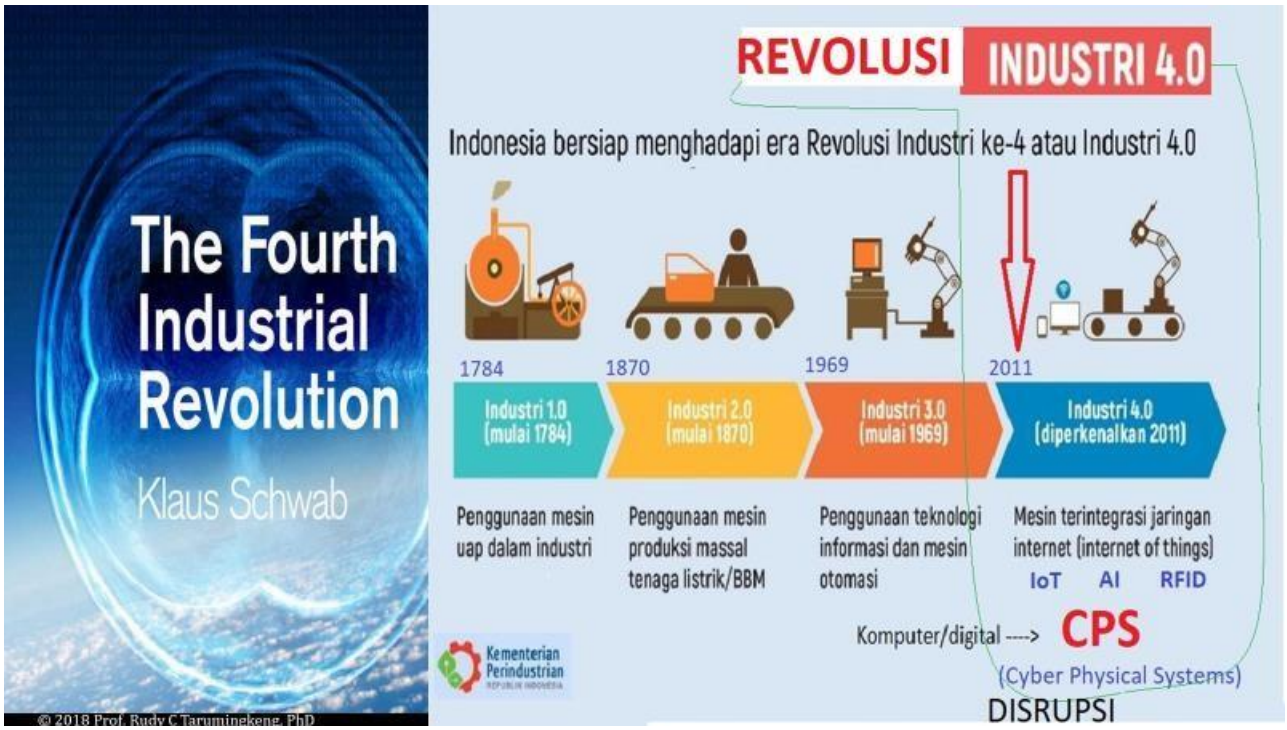

Figure 4. Industrial Revolution 1, 2, 3, and 4.0

Source: https://id.wikipedia.org/wiki/Industri_4.0

Changes in technological systems that affect the industry as stated above are known as the Industrial Revolution. In Figure 4 is given an overview of these four Industrial Revolution. Since before the 19th century (to be exact 1784), humans had known water power to move the wheel, steam power to drive the steam engine (the first train and steamship). This is the first Industrial Revolution. The second Industrial Revolution (RevIn 2.0) began in the late 19th century (precisely 1870) which was marked by the discovery of petroleum-fueled engines, mass production with conveyor belts and the use of electricity in industry. The third industrial revolution era (RevIn 3.0) was marked by the invention of computers and the use of robotics and automation in industry in 1969, while the fourth Industrial Revolution Era (4.0) began in 2011.

5. CPS - Physical Cyber System

As mentioned in ad. 3 regarding disruption, Pervasive Computing marking the current Industrial Revolution 4.0 era. Pervasive computing is the involvement of computers that are pervasive and spread throughout everyday human life as a whole. The current Digital Revolution is the basis of Technology 4.0, the Cyber Physical System-based revolution, a combination of digital, physical, and biological domains that are ubiquitous (always present, anytime and anywhere). This is exemplified by mobile supercomputing, intelligent robots (smart robots), cars without drivers, genetic editing, etc.

Figure 5. Summary of the Digital Revolution Strategy in the Industrial Era 4.0
Source: Segars, Albert H. 2018 Seven Technologies Remaking The World. An MIT SMR Executive Guide, March 2018

Figure 5 provides a diagram of the Digital Revolution Strategy in the Industrial Era 4.0 - the description of the use of digital technology for human life, is covered in four aspects:

1. Health Aspect (Health),
2. Learning Aspects (Learning),
3. Trade and Trade Aspects
4. Environmental aspects

There are seven types of core technologies covered by these four aspects, namely:

1. Comprehensive wireless network (wireless mesh networks)
2. Nano technology
3. Robotics
4. Machine learning
5. 3D-printing
6. Biotechnology
7. Pervasive computing

Furthermore, so that these seven digital technologies are able to function for human needs, each of these technologies has three distinct special abilities, namely:

1. Intelligence: the ability to receive stimulation of the situation and the environment then interpret it and take appropriate actions to be carried out.
2. Interface (Natural interface): the ability to take action in accordance with the nature and behavior of human intuition and physical objects, such as movement and gesture and other biomechanical movements.
3. Ubiquity (omnipresence): always exist everywhere for transactions between objects, machines, objects / goods and people.

These three technologies can be presented in our everyday objects. The seven core technologies above are now changing every dimension of human life, especially those related to aspects of health, learning, environment and trade.

6. Digital Technology and Millennial Generation

The digital technology that we do now through computing and communication tools such as cameras, computers, smartphones etc. is closely related to present human generation. In Figure 6 is given a diagram of the human generations from 1925-2025. In the context of this discussion, the focus of our attention is Generation X (born 1965-1980), Generation Y (born 1981-1994), Generation Z (born 1995-2010) and Generation-α (Alpha) born 2011-2025. Most teachers / lecturers are now from Generation X and Y while students are mostly Generation Z and α (which are also considered as digital generations).

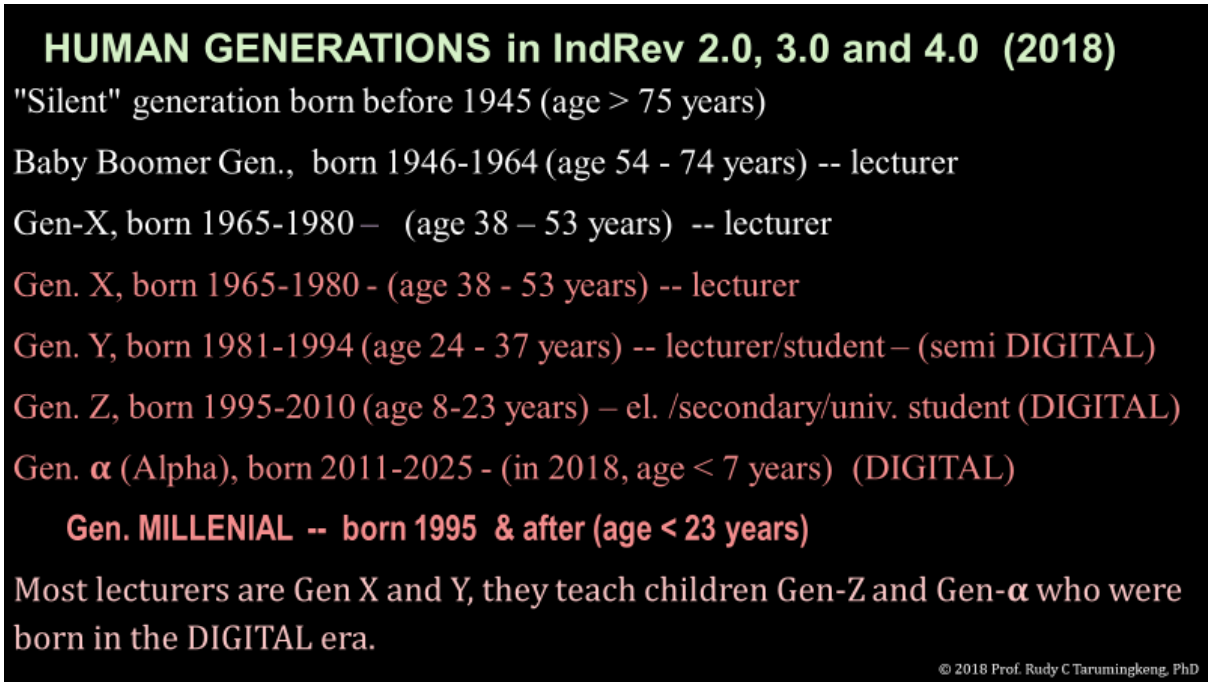

Figure 6. Human generations from 1925-2025

The use of computers in the Industrial Revolution 3 era has colored the lives of most of today's teachers and lecturers, those who were born between 1960 and 1994 (Generation X and Y) now they are in the Rev. In-4 era teaching Generation Z children and **α** (Alpha)] - also called MILLENIAL children. Millennial children from a young age (under the age of 10) generally have "hang out" with computers / smartphones - digital technology is not "new stuff" for them. In this RevInd-4 era, teachers / lecturers must be ready to equip their digital knowledge to teach millennial children (born since 1995) - if not, they will laugh at by the students. This millennial generation is the target of our education now. Most of the millennial children from a young age (under 10 years) everyday "hang out" with computers and smartphones so digital technology is not "new stuff" for them. What about the competencies and capacities of the lecturers who teach these millennial children? Surely our lecturers have to equipped themselves with up-to-date knowledge to educate, guide and direct our children so that they will master science and help transform the world into a better place, better quality habitat for the benefit of humanity. We no longer teach them the obsolete sciences that we studied 30, 20 or 10 years ago because the era of millennial children now requires tips on creativity and innovation, the ability to adapt to change - they need to be able to survive and maintain life in the post disrupted era.

In the next ten years, besides we might no longer need tailors, sales people, travel agents, library employees etc. because of CPS technology, so the future campus might not need a lot more professors / lecturers. The knowledge provided by lecturers / teachers today may not be needed in professionalism in 2020 because it can be done by CPS-based smart machines. What is needed are mentors to help students -direct them to what teaching materials to look for from search engines that are directly connected to "big data" science and technology.

7. Closing points

- Our education system that developed in the industrial era before RevIn-4.0 has now become obsolete and less effective in anticipating the future.
- Because it is now the age of internet and digital media, children have access to all information and subject matter in the world - but there are concerns that there can be loss of control.
- What is the competence of the lecturer / teacher in the "now" era? Lecturers / teachers need "upskilling": increase competence and capacity, according to the demands of RevIn-4.
- Need to quickly adapt to change because current learning leads to "adaptive learning".
- Improve and develop students' abilities in tips on creativity and innovation, accepting changes in the post-disruption era.
- Prepare students to master the knowledge needed to transform the world into a better, better quality habitat for the benefit of humanity.
- Prepare a generation that is strong and has integrity in national, state and community life

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