STEM (STEAM) Evolution – Understanding the Foundation of World Economic Development

Dr. Chandra Embuldeniya

This article will explore two things. The evolution of STEM and the impact on the economy and the society it can make in the future. It is written for the readership of Vidurava Science Magazine. I hope it throws enough light into STEM that is now attracting the attention of our students.

1. What is STEM

STEM is an acronym for Science, Technology, Engineering and Mathematics. We are quite familiar with Science and Mathematics. Science has physical and biological sciences such as physics, chemistry, biology, zoology and botany within it. Mathematics is the discipline of solving unknowns using variables and numbers. Technology is explained by the ability of these sciences to produce solutions to real life problems. Engineering is a concept in the minds of students at the school level. Engineering represents the designs and the constructions using the knowhow derived from the sciences.

2. What is STEAM

The sciences cannot stand the test of emotional recognition without humanities, social sciences and arts. Arts and commerce are fields that engage over 70% of our student population in schools. We naturally want to know if Arts and Commerce would find a place in the scheme of things under STEM. Therefore, modern STEM is connected to aesthetics and forms the acronym STEAM. Aesthetics would represent the arts, social sciences, humanities and includes other subjects such as economics, history, geography, and literature.

3. New Mindset - Integration of Knowledge

Our students are quite used to studying science and mathematics

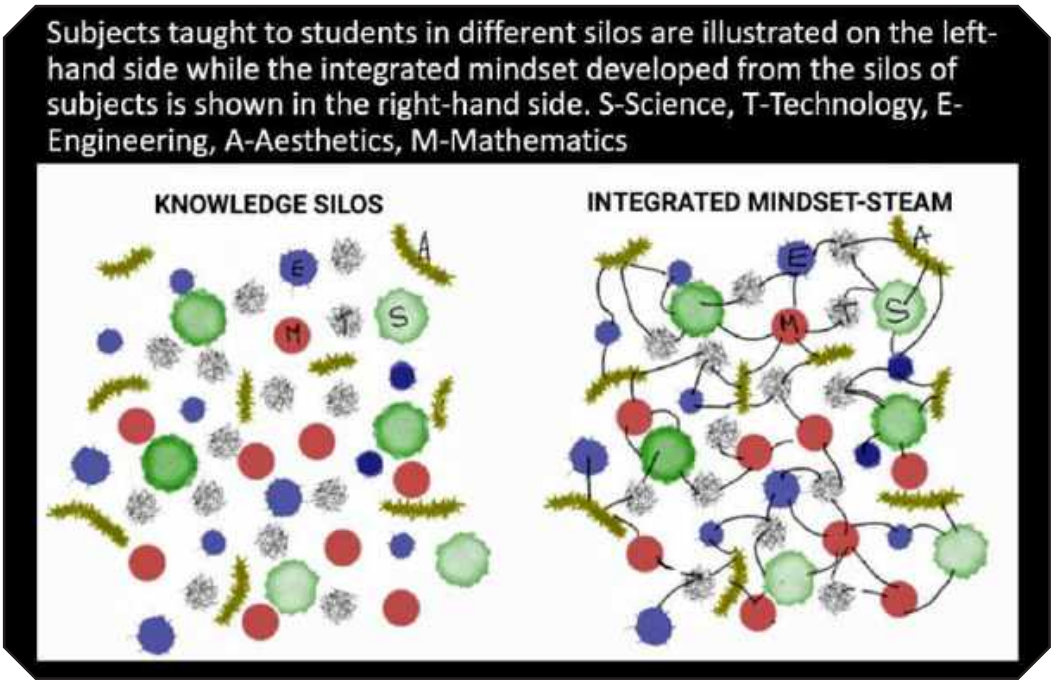

Fig 01 : Integrated Mindset in STEAM Education

while technology is studied by a few. Students learn these subjects with the theory and do various exercises answering questions, but rarely do they realize how theory can apply in real life situations. The teachers who engage in teaching these subjects have routinized this approach of teaching the theory and setting typical questions that will take the student through a journey of learning from grade 01 to grade 13. This has created a stereotype mindset in people to think within silos of those subjects. They hardly realize that silo-based thinking does not solve real life situations. The subject knowledge should be used in combination to produce real life solutions. It can only arise when students think differently. This is the integration of the mindset contained in several different silos (Figure 1). This means to enable the student to use the sciences and mathematics learnt to evolve solutions producing technologies using the designs that are emotionally appealing to people. The designing of the solution is the engineering aspect. It will involve mechanical, electrical, and civil engineering aspects when large projects such as bridges, powerplants and high-rise buildings are in need. This is possible only with the STEAM mindset. We are fortunate to have some people who have got the gist of STEAM in their mind and are not foreign to thinking in an integrated frame of mind. This is the concept of STEAM orientation.

4. Discovery – Science in History

In the history of evolution of humankind, STEAM has been the mainstay of livelihoods from very primitive levels to more advanced levels of today. This must be understood not literally but metaphorically since there was no such analysis or knowledge in the early days to associate what people have recently labeled as STEAM. The acronym STEM was used in 2001 by scientific administrators at the U.S. National Science Foundation (NSF). The organization previously used the acronym SMET when referring to the career fields in those disciplines or a curriculum that integrated knowledge and skills from those fields. On December 15, 2015, US enacted a law "Every Student Succeeds". The law includes mandates, and funding, to provide STEAM education in schools.

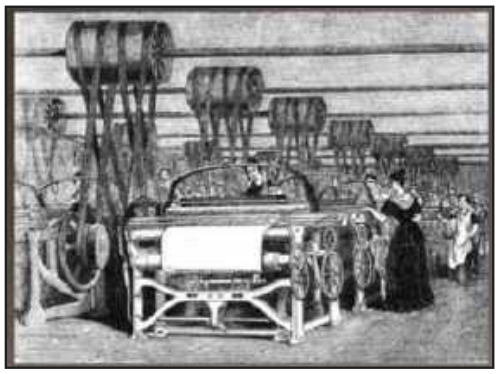

Fig 02 : Steam power used to run cotton fabric mill – 1st Industrial Revolution

5. Geological Evolution

Quite apart from the usage of the acronyms STEM and STEAM, science has made the difference to the world towards economic development. History of evolution gives us a very effective learning tool on how STEAM came to be adopted and how it made a huge social impact eventually making better standards of living for people. Let's take a brief look at the geological evolution of earth, and then the cultural evolution of humankind to get a better perspective of STEAM entry into the world. Scientists have estimated that geological evolution started 14.7 billion years ago with the formation of the universe, and the formation of the earth 4.5 billion years ago . It appears to have taken ten billion years for the formation of the earth after the formation of the universe. The first apes (early Miocene period), having an enlarged brain appeared 25 million years ago. The primitive tools came to be used 2.5 million years ago with the start of Quaternary ice-age. This appears to be the first use of technology in the world. Evidence of first stone tools

Fig 03 : Automobile manufacturing factory - 2nd Industrial Revolution

Fig 04 : Automobile Manufacturing – 3rd Industrial Revolution

appeared in Ethiopia. First human *(Homo habilis)* using hand axes appeared in Africa 2 million years ago. The renowned Neanderthals *(H. sapiens neanderthalis)* lived in Europe and Asia 130,000 years ago. About 34,000 years back Cro-magnons in Europe using bone tools and using full language to communicate replaced Neanderthals. This era was very primitive and slow in the evolution of technology.

6. Cultural Evolution of Mankind

Evidently people progressed rapidly with the cultural evolution that started from this point. Hunter gatherer nomads lived from 32,400 years up till about 10,000 years when humans started domesticating animals such as goats and pigs. Agricultural farming and settlements developed from 9,500 years ago with the cultivation of wheat and barley (Mesopotamia, modern Iraq). Naturally the people of that era had found the use of primitive technology using knowledge gained by trial and error. Writing began in various forms in the last 5,000 years as seen in hieroglyphics (Egypt), and cuneiform (Mesopotamia, Egypt). The iron age started 2,700 years ago signaling the transformation of industrial activity. Technologies such as the use of abacus by Romans, use of magnetic compass (China), first block printing (China), invention of astronomical clock (China), invention of porcelain (China), explosives (China) were witnessed. Quite in recent history the rise of individuality, imagination, innovation, first moveable-type printing (Europe), exploration of America and India by Europeans using sailing ships, theory of earth revolving around sun (Copernicus, Poland, 1543AD), discovery of laws of gravity (Newton, UK, Principia 1687AD), birth of modern physics, rapid colonization of America and India by Europeans, cataloguing of organisms by genera and species (Linnaeus, Sweden, Systema Naturae 1735), and invention of steam powered engine 250 years ago (Watt, Scotland, 1769) were the hallmarks of success in discovery.

7. Industrial Revolutions

The First Industrial Revolution – the 1st STEAM Revolution
Having seen the evolution of humankind up to this point we now step into the industrial age with the 1st industrial revolution which started with the invention of steam driven machines using coal power. This is the start of the STEAM revolution that made quantum leaps

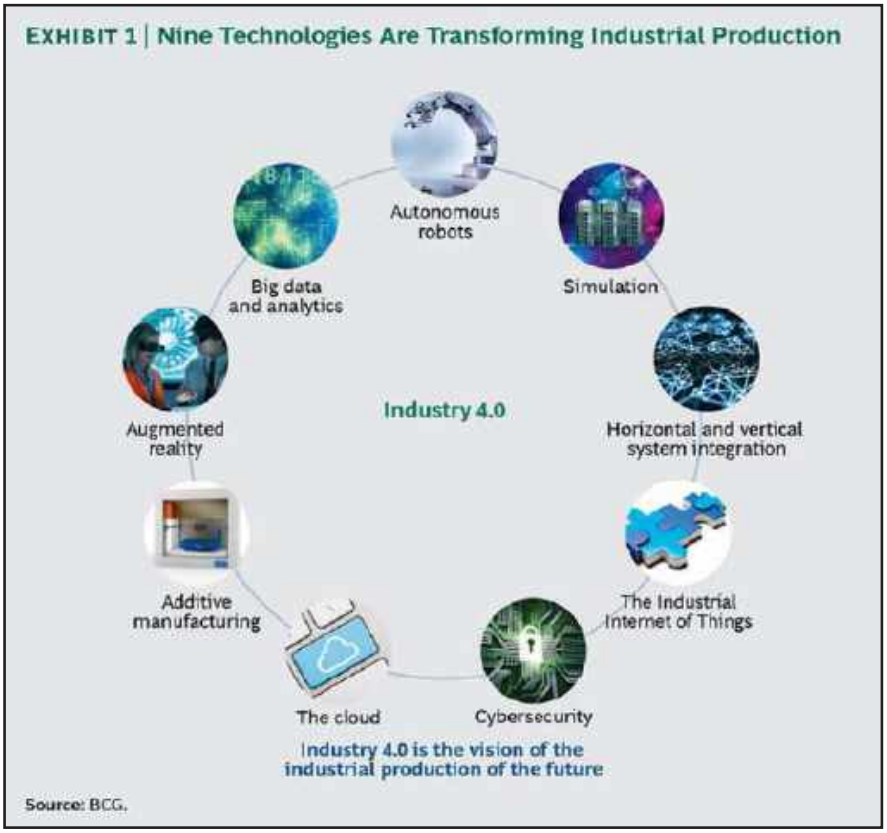

Fig 05 : The Digitally Connected World - 4th Industrial Revolutions.

Fig 06 : Both the pilot and the cameraman replaced but more jobs created on ground to manage the new operation

in economic development. The 1st industrial revolution followed a slow period of industrialization, from the beginning of the 18th century to the beginning of the 19th century. (Figure 2)
During this period the emergence of mechanization started replacing manual work with machines. An impact was agriculture taking a lesser place compared with industry as the driver of production economy. Mass extraction of coal started to fuel mechanization using the steam engine. Inventions such as forging and new skills in metal shaping helped evolve the mechanized factories.
By the 19th century, stationary steam engines powered the factories of the Industrial Revolution. Steam engines replaced the sail for ships. The factory production of textiles, and iron and steel started in UK. Reciprocating engine, the piston and cylinder type of steam engines were the main source of power until the early 20th century.

The Second Industrial Revolution – the 2nd STEAM Revolution

The 2nd industrial revolution is generally dated between 1870 and 1914 (the beginning of World War I) (Figure 3). It was a period when advances in steel production, electricity and petroleum with a series of innovations that changed life and livelihoods. Steel production became cost effective and railroad transportation revolutionized the movement of goods and people. Electricity was developed from breakthroughs in basic physics (Universities in UK) which led to the telegraph (communication system). Then came the telephone which has a long history of evolution with many inventors and finally Antonio Meucci and Alexander Graham Bell shared credit. Electrification of cities and homes was driven by Thomas Edison in the USA. The expansion of telegraph lines facilitated transportation causing unprecedented movement of people and ideas, which gave rise to a new wave of globalization. Chemical synthesis also developed to produce synthetic fabric, dyes and fertilizer. Gas and water supply systems, and sewage removal systems evolved in many cities. Electrical power and telephones systems were introduced. Factory electrification and production line technology came to be used. Fossil oil replaced coal. Daimler and Benz in Germany developed the internal combustion engine using oil and electricity. Highways and the transport systems developed.

The Third Industrial Revolution – the 3rd STEAM Revolution

The 3rd Industrial Revolution started in the second half of the 20th century, with the emergence of nuclear energy. The 3rd industrial revolution saw the rise of electronics with the introduction of the transistor and then replacing it with the microprocessor. Telecommunications also revolutionized, and computers came to be used. With the new introduction of microprocessors, the production of miniaturized material started. This technology was the key to space research and biotechnology. In industry the era of high-level automation in production started. Automation was made possible with the programmable logic controllers (PLCs) and robots. Thus the hallmark of the third industrial revolution used electronics and information technology to automate production (Figure 4). The first industrial revolution used water and steam to mechanize

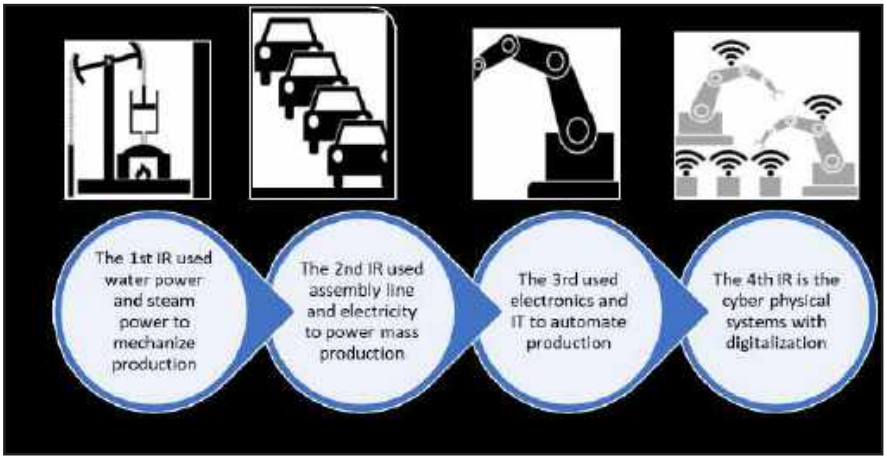

Fig 07 : The Four Industrial Revolutions at a glance – These were clearly STEAM revolutions

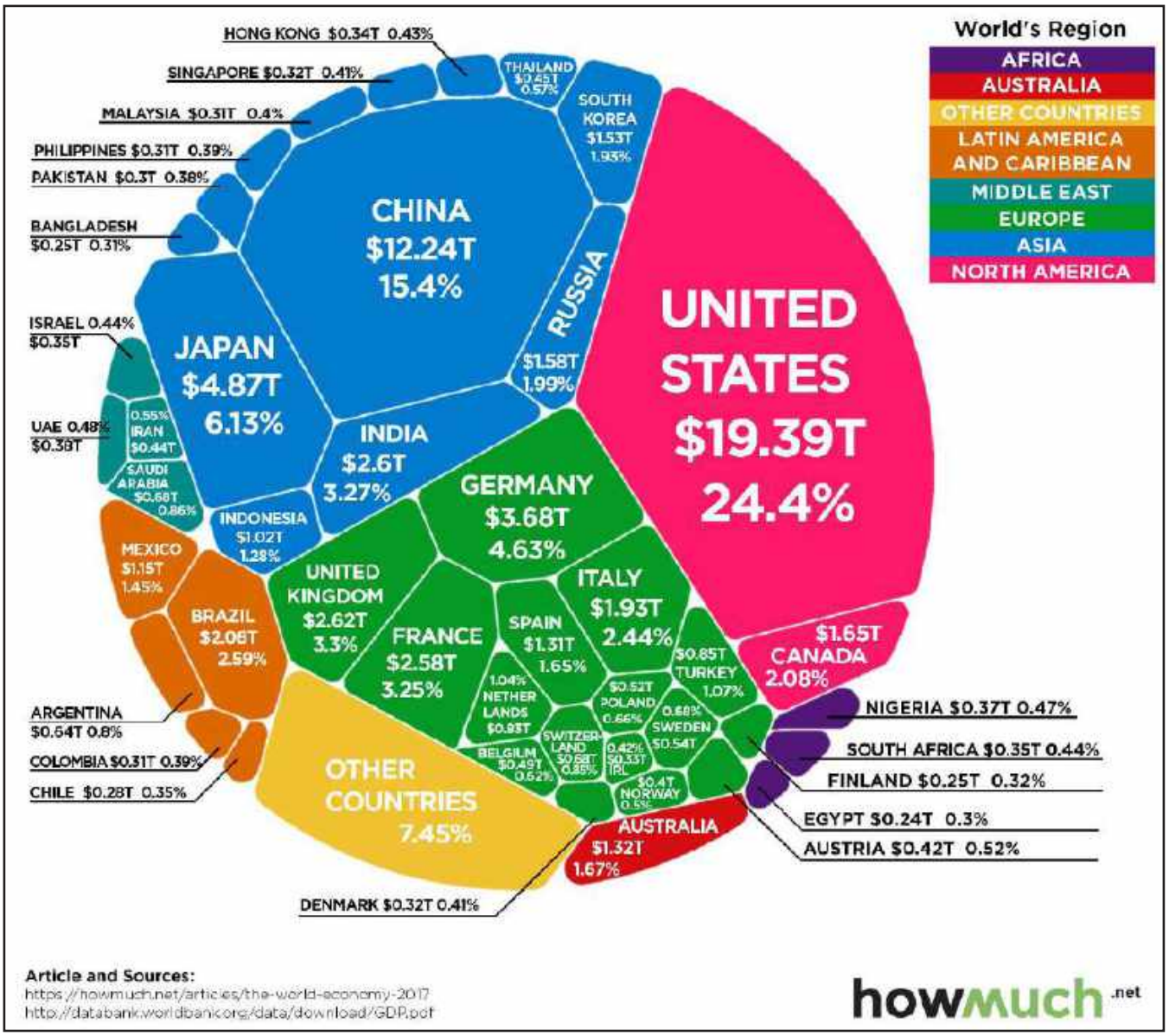

Fig 08 : World GDP - All Countries who are in this picture have STEAM oriented economic development

production, the second used electric energy to create mass production and the third used the microprocessors and information technology.

The Fourth Industrial Revolution – the 1st Digitization Revolution

Now we are facing the 4th industrial revolution which is labeled 'Industry 4', 'I4' or '4IR'. The hallmark of the 4IR is digitization. Its creation is founded on the Internet. All three previous revolutions took advantage of new type of energy while this revolution took advantage of the internet and the digitization. This digitalization helps in the creation of a virtual world to run the real physical world.

In the previous revolutions we collected data from history while the 4IR enables real time connections with the fast gathering of data on the internet (Figure 5). Thus, production facilities enable their interaction in real time to get the best results. It makes communication among different people and connected machines in a production line possible using technology such as Cloud, Big Data, Analytics and the Industrial Internet of Things (IoT). This makes more robots to come into the production lines replacing the human interventions. Maintenance of sophisticated machines can be done more effectively before failures occur.

Big data and analytics make real time decisions, effective inventory management, goods delivered to homes from the factory, and real time movement of people between jobs easier. The machines keep learning and improving technology with machine learning. One of the advantages of 4IR is that it is based on greater intelligence gathering using real time data. It can economize on energy using wind, sun and geothermal energy. It is also anticipated to create new jobs while most of the jobs that we know today will disappear to give way to machines.

8. Opportunity for Sri Lankan Students'

It is easy to realize that people who invented the technologies and innovated them further during the past three centuries did so with the application of science, technology, engineering, aesthetics and mathematics. This indicates that STEAM has been the driver of development that gave rise to the living standards today. The current position of the developed STEAM countries can be seen in Figure 8. All other countries are left with only 7.4% of the world GDP. This means that Sri Lanka needs full commitment of our students to rise with STEAM to help develop the economy.

The 4IR is a different challenge. The reason is because while it took three centuries from the beginning of the 16th century to travel through three industry revolutions, the fourth industry revolution is happening much faster (Figure 7). It is changing the technologies around us within months. Therefore, it is imperative for our students to get ready to face the future armed with relevant knowledge. This gives you the best reason to adopt STEAM learning process.

The STEAM Journal quotes, "In China, they are grasping all the expertise they can concerning STEAM education because they believe it will allow the labels of the future to say "invented in China" rather than "made in China." It is a cash cow, having your citizenry. A more interesting way to look at, or justify building STEAM programs in schools is that STEAM modes of learning make students more creative, and more empathetic. Creativity, and empathy, lead to happiness, trained via STEAM!". This is a truly inspiring statement for wanting to make STEAM a new learning experience in Sri Lanka for our students. It confirms our belief that STEAM is the path to innovations which generates economic development, and on the other hand, it makes it fun learning. One cannot seek a better way to get children into learning for a greater purpose than passing a mere school test.

Sri Lanka requires a complete transformation of the students' mindset to adopt value creation. This is about economic value creation. First, they must understand the meaning of value since many of the services in Sri Lanka are provided as a free service, and now taken for granted as a right of citizens. This has led to the loss of intrinsic economic value, and the fact that the service provider, the government, must raise these monies from others who create wealth by taxing. The next thing is, once they enter society how should their efforts be transformed from receiving free gifts to earning by creating wealth. How does one create wealth? This is the most valued question that teachers should provide answers for the students to develop a transformative mindset. Creating wealth comes with an idea that is marketable which can be either a product or service. Since children leave school either to join the higher learning ladder or develop vocational skills or to work in an institution, the idea of wealth creation is about entrepreneurship. That means to be working with the knowledge that one is helping value addition within the institution.

Be it the university, vocational training institution or the paid workplace, it is necessary to carry the thought that one must be contributing positively to value than behaving negatively to bring down the value.

The solutions to real life problems are found by bringing several disciplines together integrated within the solution. As such for a student to be able to see that they need to look outside the framework of the silos of subjects and draw from other subjects to have such an integrated activity is the right approach. This is the teachers' responsibility to create such a mindset in a student.

Dr. Chandra Embuldeniya
Founder Vice Chancellor (2004-2011) of Uva Wellassa University in Sri Lanka.
Chairman, NSF Working Committee on STEM Education.
0773837405
chandrajembuldeniya@gmail.com