The Role of Cyber Physical Systems to improve Smart Learning Environments

A.Neela Madheswari, S.Ambareesh

Abstract*: *The growth of technologies lead to a lot of improvements in almost all the fields. A huge man power is used in all the fields especially in manufacturing sectors. We can reduce man power mainly for the work which can be done by machines in an efficient manner. Industry 4.0 is focusing mainly for this purpose. Cyber physical systems are used to build a system with better communication and data collection in a shared and collaborative manner from all components of that system in safe and reliable manner. As though CPS is starting its implementation in all the fields this work deals mainly with role of cyber physical systems for smart learning environments. This work forms a basic study of those systems.

Keywords*: *Cyber physical systems, smart learning environments, sensor nodes, Industry 4.0, Learning factory

I. INTRODUCTION

The technological evolution leads to growth of industries which provides us many rewards to human society such as time to market is reduced, cost of entire product development is also reduced. Industries and manufacturing companies applied various technological advancements by applying different engineering methodologies for their production of goods in a better way as per their requirements.

The cyber physical systems (CPS) provide a new way to interact with and expand the capability of physical world through computation, communication and control which are the main features for future technology development. The main objective of CPS is to integrate knowledge and engineering principles across computational and engineering disciplines. The capabilities of CPS are: i) Sensing using artificial intelligence assistance and smart grids, ii) Automation for example, using automated controlled vehicles, and iii) simulation used for resource utilization and robotic process automation.

During the first industrial revolution water and steam power engines and other types of machine tools are used. In the second industrial evolution, steel and electricity are used. During the third industrial evolution, more electronic and computer technologies are used. Industry 4.0 introduces innovative technologies for the integration of data management, knowledge sharing, training, and embedding in production. Gartner predicts top 10 technologies that are ruling us during 2019 and one of them is 5g technologies. These technologies are helpful for emerging Industry 4.0. Due to the evolution Industry 4.0, there are various implications such as i) manufacturers side: improved performance, expansion and profitability, ii) operations side: improved efficiency, better product design and service approach for equipment sales, iii) distributors side: supplier economics visibility, better pricing and efficient supply chain management. There are various technological pillars support this Industry 4.0 namely: i) Internet of Things, ii) Analytics, iii) Cyber security, iv) Big data, v) Cyber physical systems, and vi) virtual reality.

CPS are helpful in various fields applications namely: i) disabled people: equipped with wearable devices, smart homes and robotics, ii) health care: early diagnosis and quick relief from disease, iii) agriculture and food supply: incorporate food safety and smart agriculture, iv) manufacturing: smart factories with automation in most of the product production flows, v) energy and critical infrastructure: reduce economic and electrical energy for resources and better utilization of resources, vi) logistics and transport: autonomous and driverless transport systems, vii) security and safety: smart health care systems, and viii) education: smart learning environments (SLE).

A smart learning environment must i) detect hazards in labs or fire within the campus, ii) health monitoring of staffs and students in the learning environment, iii) maintain equipment for safety and security, iv) smart utilization of resources inside the campus, v) entire monitoring activity of all subsystems of the campus, and vi) necessary steps in controlling all units without any disaster.

As far as education is concerned, there are a few forms of evolution happened. Initially gurus or facilitators teach the science and technology to their students without any specific inventions. Later paper work came into a new invention where it leads to a dramatic improvement in learning environment. Universities came into existence to educate people or youth. Then calculating devices are used to aid teaching in complicated mathematical problem solving. With the advent of new technologies, we are enjoying with various electronic gadgets such as laptops, tablets, smart devices, and so on for improving the educational level or simplifying the concepts such that students can understand the science and technology in an easier manner. Evolution of open source software plays a major role to involve people and get trained using open source software for various problem solving purposes. Flipped classrooms play a major role in improving studies or learning among the students

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community. With the advent of Information and Communication Technologies, online courses are organized from reputed universities so that any person who resides anywhere in the world will get an option to undergone training or courses from any of the reputed institutions who provide courses in online. Automatic report and result generation, automatic grading systems can be accomplished in an easier manner. Smart technologies such as clouds and networks act as a backbone for accomplishing different achievements in the education.

There are a lot of resources available to get training either it can be at school level or at higher studies level oe even in software tools and automations. As per Gartner, new technologies such as immersive experience, augmented reality are also helpful to improve education. Digital twins also one of the upcoming fields of technology where any process can be simulated and studied without creating actual objects or contents. This will helpful further in improving the productivity or accuracy of any production systems. Virtual reality also plays a major role where we can get trained for any kind of system to be operated before entering into the real environment scenario.

CPS scientists and engineers to be trained to have a common knowledge framework and utilize the technological advancement for getting into the smart learning and improved environment such that the future generations may succeeds to a very fast learning environments.

II. A ROAD MAP ON CYBER PHYSICAL SYSTEMS

A. Evolution of CPS

A mechanism that control and monitor based on computer algorithms and bounded together with its users through Internet is termed as cyber physical system. This system is engineered and built from, and depends on the virtual combination of physical components and computational algorithms.

Cyber means new things that are made by computers or discrete and logical computation, communication and control. Physical means things that are nature or connected with a person's body characterized or produced by the forces and operations of physics. The system that bridges computers and the communication systems with real world is known as cyber physical systems. The operations on CPS are monitored, controlled and coordinated as well as integrated using computing and communication systems. Some examples for CPS are: factory automation, process control, defense systems, aerospace systems, robot systems, intelligent highways, etc. CPS must communicate with the real world in a proper, secure, safer and efficient manner [1].

The integration of real world systems and computing systems that are networked together emerged into a new generation of engineered systems i.e. cyber physical systems. The CPS is composed of various elements like computation, communication and control components which are combined together tightly with physical processes of different nature, example, mechanical, electrical and chemical. These CPS systems make use of two main systems namely: computation systems and communication systems that are interacted with the real world systems, things or objects [2].

The availability of the term 'cyber-physical' is explicitly mentioned in five major scientific publishers and is shown in figure 1. The term cyber-physical is chosen since it composes various applications and aspects of the CPS. Before, there are many articles related to the origin of CPS and its concepts and notions are mentioned. The highlighted figure is used to focus CPS trending notion in literature whatever the field of research and the publisher. As per the picture, during 2012 to 2017, the total number of publications reached to 1000, also 40% increase in average per year is noticed which implies the high level acceptance of the notion for CPS. Also the picture shows that IEEE was the earlier days publisher for CPS concepts and later it was widespread in other publishers in the coming years such as Elsevier, Springer, Taylor and Francis and Wiley publishers. Thus the publication regarding CPS is disseminated through various scientific publishers [3].

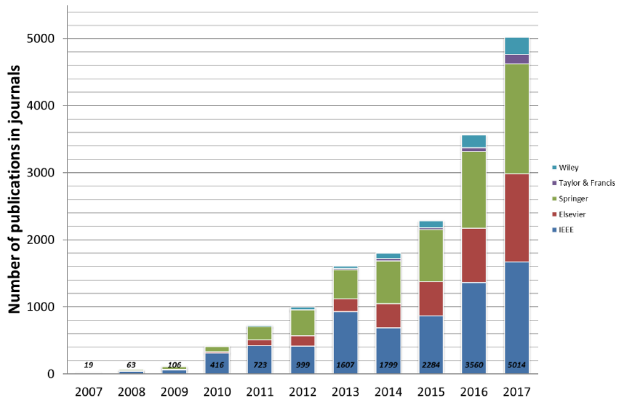

Fig. 1.CPS notion dissemination in literature [3]

B. Elements and framework of CPS

In order to provide mass production with system automation and control in manufacturing industries the concept of Industry 4.0 is evolved. To achieve that, CPS has to extend its support. Sensors are used from base level to gather information from the real world environment. Sensors are actually used widely in IoT (Internet of Things), which is an integrated world of future Internet. Using IoT, any object can be connected and talk together. For achieving this, many technologies such as near field communication, radio frequency identification, infrared sensors, etc are used. The next level in CPS is controllers and programmable logic controllers which are used to collect the information from sensors that are distributed in various places in a correct manner. There are a number of sensors used for data collection and the data velocity, variety and volume are difficult to handle and hence the programmable logic controller which is used to control the flow of automation. The information that is collected from the distributed networks has to be gathered and given into the high-performance computers using networks, which is the next level of CPS. The next level is the algorithms and simulations for analyzing with the help of digital environments. The simulation environment is helpful for evaluating multiple scenarios without any failures and also to reduce risk in the real world

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environment. Simulation helps to maintain zero defect rate, reduction in manufacturing cost and thus automatically improve business processes. Automation and control are in the next level of CPS. Automation systems are configured through their lifecycle and application modeling, visualization and reuse of those systems can be achieved in a better manner [4].

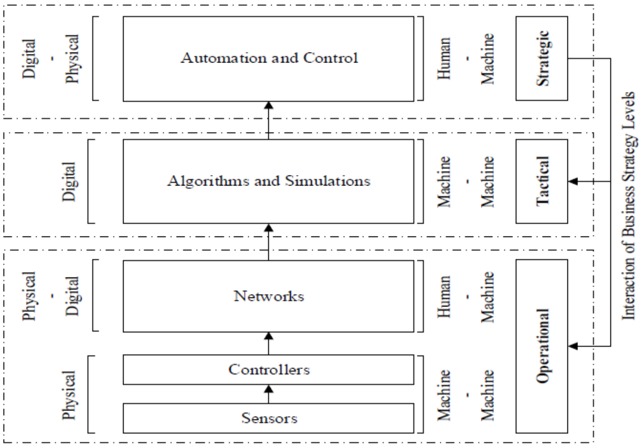

Fig. 2.Elements of CPS [4]

III. THE INDUSTRY 4.0

A. Industrial evolution

Industry 4.0 stands for fourth Industrial revolution. Other related terms are Industrial Internet, Digital factory. Industry 4.0 is responsible for digitizing and integrating processes vertically across the entire organization, from product development to logistics and services. All the processes are available in real time and supported by augmented reality, CPS, and networks.

There is an evolution in industries starting from the usage of steam engines to the current CPS. There are various stages involved in the evolution from Industry 1.0 to Industry 4.0 [5]. The main feature involved is the reduction of manual work in the industrial process. It is shown in figure 3.

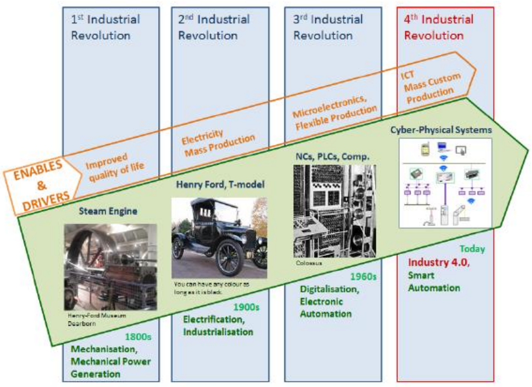

Fig. 3.Industrial revolutions [5]

During 1800s the first industrial revolution started by introducing mechanical power generation. This is the first initiative turns manual work to industrial process. Mainly it is helpful in various textile industries. The main goal is to provide improved quality of life. The second industrial revolution is charged with electrification which enabled industrialization and mass production.

The third revolution is powered with digitalization and electronic automation. This will leads to flexible production and various types of products are manufactured on production lines with the support of programmable machines. Still we cannot expect more flexibility in these systems for production quantity.

The fourth evolution is powered by development of Information and Communication Technologies. The technology involved behind this evolution is CPS smart automation that does not has centralized control but has advanced connectivity. Thus main goal here is to achieve flexible mass custom production and flexibility in production quantity.

B. Industry 4.0 Design principles

The design principles for Industry 4.0 are given below [6]:

- Interoperability: The components of CPS such as humans, smart factories, networks connected together using Internet of Things and Internet services.
- Virtualization: Virtual copies of smart factories can be created using virtualization concept.
- Decentralization: CPS components are smart which means they can make decision on their own.
- Real-time capability: The collection and analysis of data is also one of the main functions of the CPS that should be done immediately.
- Service orientation: Internet services are used to provide services through Internet of services.
- Modularity: There are various elements involved in CPS and every individual module will play its own roles.

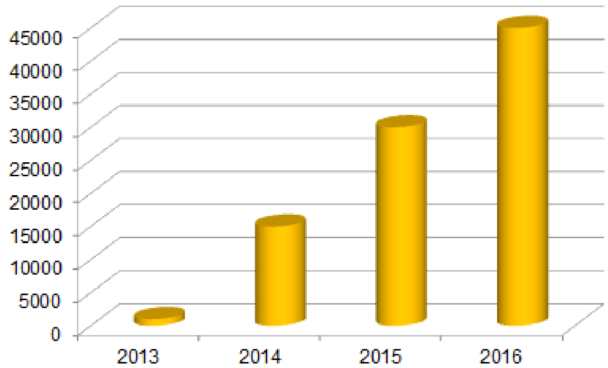

Fig. 4.Robots in Amazon Workhouses [6]

In medical engineering, Industry 4.0 is implemented by a German manufauturing industry, Siemens. Artificial knee and hip joints are customized by engineers according to patients. Siemens produced an implant using new software and steering solutions within 3 to 4 hours. Figure 4 shows the role of robots in Amazon workhouses.

C. Smart factories

Figure 5 depicts the Industry 4.0 smart factory. In a reconfigurable manufacturing system, the core process is digital to physical conversion. The latest advances in the development of a manufacturing system are the reconfigurable manufacturing systems. First step is fixing production lines with machines dedicated to performance of specific tasks and hence one product will be produced. Next step is production systems were made flexible with programmable machines that will produce a variety of different products. There is no flexibility in production capacity. Reconfigurable manufacturing systems are helpful for ever-changing market requirements of required quantity of products and types using adapting hardware and software components.

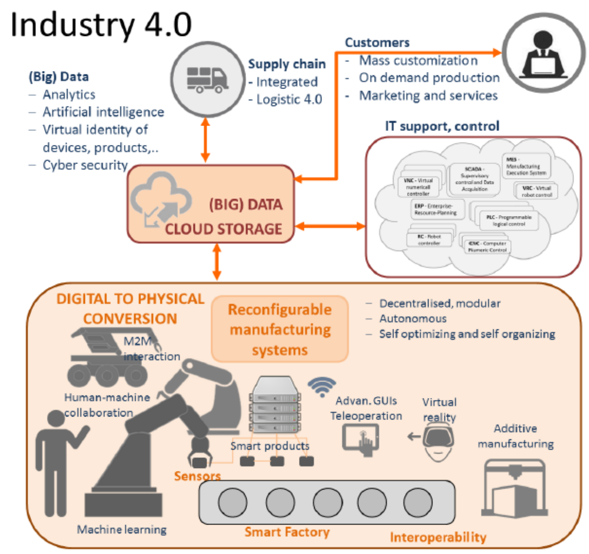

Fig. 5.Industry 4.0 Smart factory [5]

In Industry 4.0 factory machines are physical systems and CPS that are integrated with ICT components. These systems are autonomous i.e. these systems can make their own decisions based on data captured in real time environment, recorded past behavior analysis and machine learning algorithms. Mobile agents are used heavily and also robots used are helpful for performing self-optimization.

Products manufactured are 'smart' with embedded sensors which are used through wireless network which are required for real-time data collection, for measuring environment conditions and these products possess control and processing capabilities. The smart products can able to monitor their own state during their lifetime. This is required for proactive and condition-based maintenance for products embedded in large systems. Interoperability and connectivity are important components of Industry 4.0.

Connectivity should be established so that the continuous flow of information between the devices, machines, manufacturing systems and actors can be maintained using Industrial IoT. Human-to-machine interaction is also needed to make entire system automation and research work is in progress regarding collaborative robotics. The tasks that are done completely manually prior can be automated to make the tasks to do by robots entirely to improve production lines [6], [7].

D. Reference Architecture Model Industry 4.0 (RAMI 4.0)

It is realized that in most companies Industry 4.0 concept is already available with equipment and technologies. To address the standardization issue for Industry 4.0, a reference architecture model was developed in Germany as given in figure 6.

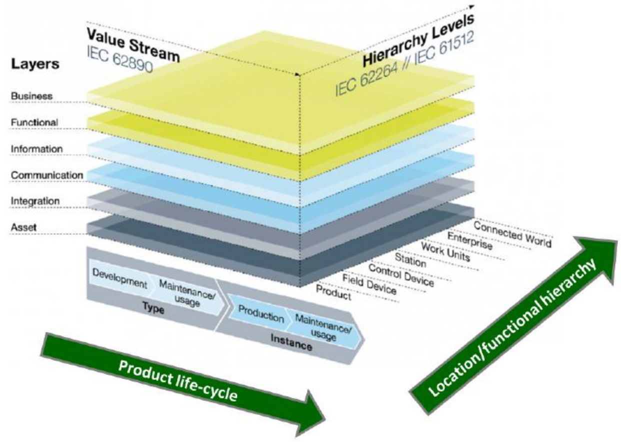

Fig. 6.Industry 4.0 Smart factory [5]

The first dimension of the RAMI 4.0 addresses two elements namely: type and instance. As long as an idea, a concept, or a product is still a plan and is not available yet, it is called type. The second dimension of the model deals with location, functional hierarchy from the product to the connected world. The third dimension of the RAMI 4.0 model is organized in functional layers as: i) Asset layer comprises physical components such as robots, PLCs, and software ideas, ii) Integration layer provides information of the form to be processed digitally, iii) Communication layer standardizes communication using uniform data format and predefined protocols, iv) Information layer provides functionality of processing and integrating available data into useful information, v) Functional layer includes formal descriptions of functions, vi) Business layer provides mapping of the business model and business processes.

E. Role of Industry 4.0 in India

Collaborative robots (co-bots) were used by one of the largest two-wheeler manufacturers in India. The employees were worked collaboratively with co-bots for industrial processes such as welding, bolt tightening, etc. As a consequence, production increased from 507 vehicles per person per year to 804 units per person per year and also maintaining standards. One of the multinational companies from Mumbai used intelligent plant framework to improve their work efficiency. This framework also used to reduce the wastage and organize production flows. A Bengaluru-based packaging company has connected machines over a network and helps the company put predictive maintenance in place. The steps taken by government of India to promote the adoption of Industry 4.0 are [8]: i) National Manufacturing Policy 2017, ii) Centre of Excellence on IT for Industry 4.0, iii) National Programme on Artificial Intelligence, iv) Mission on Cyber-Physical systems.

F. Current status of Industry 4.0 in India

I4.0 market is expected globally to reach 13 lakhs of crores by 2023. European countries like Sweden, Austria and also countries like U.S, China, Japan have started adopting I4.0. In India, focus was given to 'Make in India' campaign. The government aims to augment the share of manufacturing in GDP to 25 percent from the current 17 percent, by 2022. A number of initiatives and policy reforms, such as implementation of GST and easing FDI policy, had been taken by the government [8]. The big data analytics market is expected to grow and reaching approximately 32 percent in the overall global market.

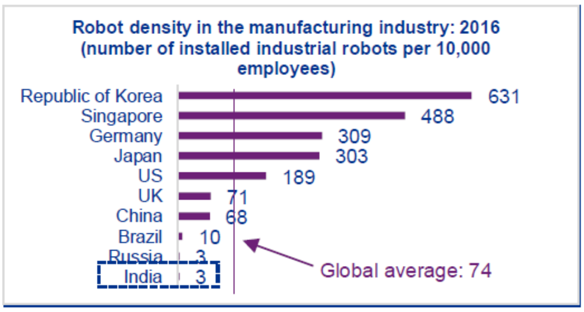

Fig. 7.Current automation rate [8]

IV. SMART LEARNING ENVIRONMENTS

Classrooms, labs, and offices are the usual learning environments. It involves the social context, psychological and pedagogical effects that made impact to students learning, achievement and their attitudes. Learning environment play a major role in schools. Learning environment helps to engage students to development of skills and cognitive perception. Physical component and psychosocial component are the two main components of the learning environment. Physical component is used to improve interaction among students, teachers and the environment. These components leads to the creating and shaping of the learning environment and made a significant impact on learning process [9].

In 2016, Universities and Colleges Information Systems Association (UCISA) published a 'Survey of Technology Enhanced Learning for Higher education in the UK' that includes learning platforms current scenarios and the future plans of educational institutions [10].

The main finding is that most of the institutions are providing virtual learning environments. Blackboard and Moodle are utilized at a huge rate by the institutions. As though few findings are given as: i) Moodle lost popularity (down from 62%), ii) New vendors raised into the market, iii) Most institutions moving towards third party hosting or software service models.

Providing wide range of types of provision for teaching learning platforms are made available such as blended learning, distance learning and open education. The increase in open education provision leads to development of FutureLearn and Blackboard's open education.

A. Impact of digital learning

Digital learning is a good promoter for college and career readiness. Learners today are using digital devices and they come to school and power down their devices. We have to utilize the power of technology to make learning relevant for all students and adults as educators. For everyday learning using technology effectively can help students to strengthen their learning experiences and build their skills. In order to stretch learners to think in different way which lead to success in global economy and rapid evolution of digital environment, technologies can be used effectively for instructional purposes [11].

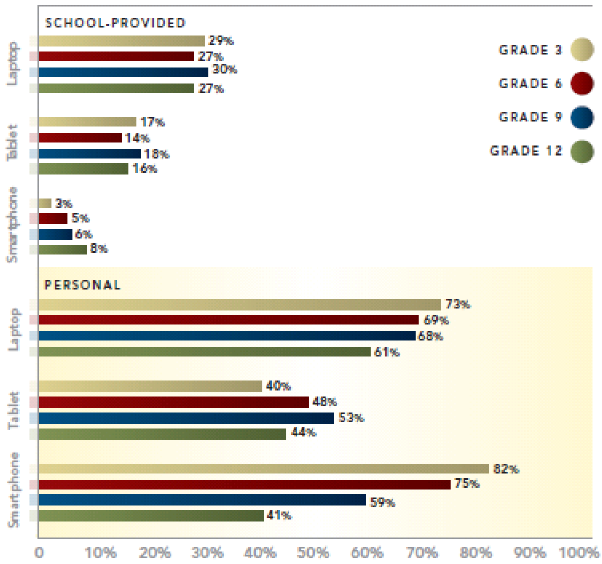

Fig. 8.Kids going with Mobile [11]

With an increase in kids going mobile, social media provides the context for digital learners to connect, collaborate and create content in ways that are especially meaningful for them. They are increasingly using a wide range of social media tools to do just that including: i) texting: 71% of high school students and 33% of middle school students communicate with others via text messages, an increase of 44% since 2008, ii) Twitter: 3 out of 10 students in grades 6-12 are using Twitter to follow others or to share 140 characters about their daily life on a regular basis, iii) Videos: Since 2007 the number of middle school students creating videos and posting them online has doubled from 15% to 30%, iv) Games: Showing a generational shift, nearly twice as many students in grades 6-8 participate in massively multiplayer online games compared to students in high school.

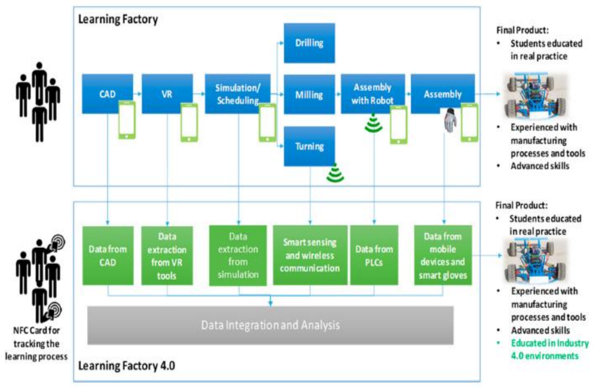

Fig. 9.Architecture of the Teaching Factory 4.0 [12]

B. The Teaching Factory 4.0 concept

In order to utilize the personal

skills, technologies and also the educational institutes and focusing on task-specific industrial problems, teaching factories are arise. To practice technical knowledge for emerging Education 4.0 concept teaching factories are essential. An example of architecture of teaching factory is proposed in [12].

The architecture of Teaching Factory 4.0 is given in figure 9. The main objective of teaching factory 4.0 is design and manufacture of electric car. At the starting stage, participants are grouped and are provided with initial requirements with necessary parts that are to be included in the designing and also available resources for the completion of the product. There are various technologies used and are integrated such as IoT, NFC (Near Field Communication), Augmented Reality (AR), Virtual Reality (VR), collaboration of human and machines, big data analytics. A communication card is provided to each group for evaluating their process. Every group has to register the start and end time and also stored useful information for every stage to a cloud database. The information can be accessed and are evaluated their performance for each stage.

C. Constructing SLE via CPS

Measuring physical quantities and react for regulating and providing appropriate services are the main function of a typical CPS. From a system perspective, communication, computation, control components are integrated in CPS to include or update cyber physical or information quantities. In order to provide meaningful services, interpretations of received data are needed. To deploy CPS, techniques for data mining and node synchronization are necessary. A typical CPS contains numerous distributed sensor nodes, actuator nodes and computation nodes from the hardware perspective. When CPS activates, sensor nodes are automatically examined the appropriate environmental conditions. Measured physical quantities are forwarded to computation nodes to perform necessary actions or for post processing [13].

There are many challenges while deploying CPS for implementing SLE. The major technical challenge is the power consumption. The CPS should have a long operation time in practice. Power supply is also one of the limitations of CPS. To deploy software or hardware minimal effort has to be put forth. The power needed should be accompanied and given by energy harvesting systems.

The second challenge is analysis and processing of data. Machine-generated data is always different from human-generated data and hence processing frameworks are needed.

The third challenge is the communication to be established among nodes. There is a need for huge communications between among a number of nodes and also there is a limitation in data transmission rate in CPS. Hence while communicating, useful and meaningful information should be transmitted to other nodes. Besides these challenges, existing educational practices should be reformed such that we can utilize CPSs for a SLE [13].

V. CONCLUSION

People are enjoying their digital life in this current era. In order to make our life simple and also in a secured manner, many evolutions of digital world has to be explored and to be used for the welfare of us. The history mentioned in this work shows the starting or growing stage for Industry 4.0 and CPS in various fields. Also it gives some essence in the construction of smart learning environments with the help of CPS. It is our boom to utilize the incoming or developing technologies and make ourselves happy leading lives.

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