An Overview of STEM Education and Industry 4.0

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Introduction

It is known that the changes in science, technology and engineering have been increasing in recent years. We understand these changes by looking at both scientific studies and inventions, new technological tools and machines and new methods which have been used in the engineering fields. From this point of view, it is able to be claimed that education systems are changed to be adopted new changes which have been seen in industry, as well. STEM education can be identified as one of new approaches to be used in education system, which also aims students to be able solve problems in their daily lives. Meanwhile it is thought STEM education must be introduced. There are some different STEM concept defines in the literature. National Reserach Council (1996), STEM is an educational and teaching approach which integrates the content and skills of science, technology, engineering and math. Herschbach (2011), states that STEM is being created by using capital letters of science, technology, engineering and math. At this point, it can be asked why countries need STEM Education and need STEM activities and applications in their education systems. To answer this question, U.S. former president Barack Obama's call to action on new developments in Industry of USA's education system can be said the reason of changes. He said "One of the things that I've been focused on as President is how we create an all-hands-on-deck approach to science, technology, engineering, and math. We need to make this a priority to train an army of new teachers in these subject areas, and to make sure that all of us as a country are lifting up these subjects for the respect that they deserve" (White House, 2013). After Obama's talk on STEM Education there were seen efforts in the USA's states. The similar efforts can also be seen in European Union (EU) and EU paid attention more efforts on STEM Education and EU (created many STEM projects such as Scientix, STEM Alliance and so on. STEM projects have also been continued by EU and European countries. At this point, the relationship STEM Education and Industry should be explained. In this context, the skills of STEM education can be stated to understand the relationship between STEM Education and Industry 4.0. The Partnership for 21st Century Skills (2011), defines 21st century's skills "collaborating, communication, critical thinking and creativity. National Research Council (2010), states 21st century's skills "nonroutine problem solving, self-development, systematic thinking, adaptability and complex communication skills. Besides them, innovation, employability and efficient team working can also be given as 21st century's skills. The 21st skills are paid attention which we are able to understand it by Obama's statements regarding USA's efforts toward STEM Education. It is clearly understood that 21st century workforce need people who are donated with 21st century skills. Gonzales, Jones & Ruiz (2014) also revealed the importance of STEM Education and its features related to industry. In their opinion completion of the first 21st century decade launched a global competitiveness pace in economical markets which had initiated an instructional paradigm shift for learning and teaching. Banks & Barleks (2014), STEM learning carries out in the real World, in this context schools work with industry including other learning centers. World Economic Forum (2016), points out according to a popular expectation that 65% of children who entering primary school today will ultimately end up working in completely new job types that do not yet exist. European Commission/EACEA/Eurydice, (2016), states that improving and promoting entrepreneurship education is one of the key policy objective for the EU and it provides skills, knowledge and attitudes that are developing an entrepreneurial culture. It is thought that the introduction of Industry 4.0 is necessary. Wang et. al. (2016), states that Industry 4.0 is the proliferation of cyber-physical systems that introduces the fourth stage of industrialization. It is useful to be given Industrial revolutions which facilitate the relationship between STEM Education and Industry. In the figure 1, the development of industry is given since 1784 till now.

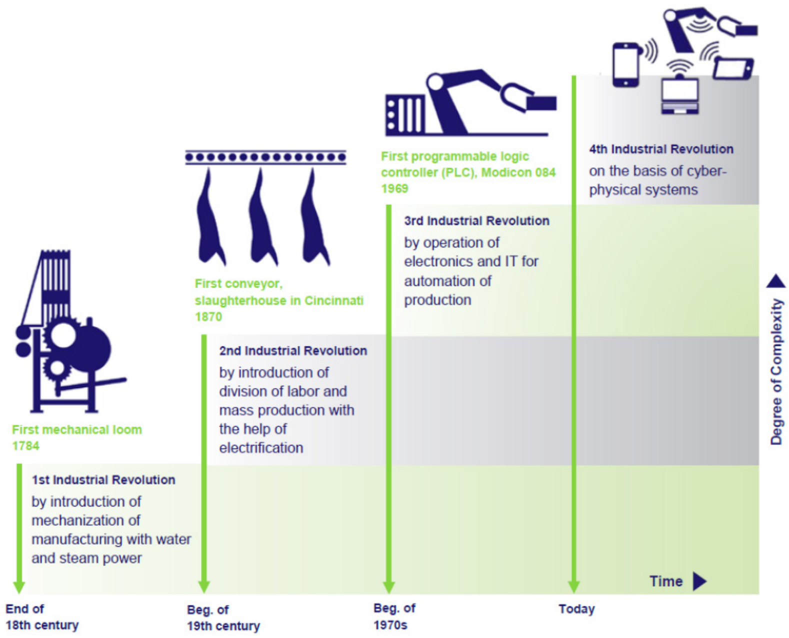

Figure 1. The Four Industrial Revolutions (graphic by Kagermann et al., 2013)

As it can be seen by looking at figure 1, first industrial revolution initiated by using steam water in the industry, the requirement energy was provided by manufacturing with water and steam power. When entering 19th century, second industrial revolution started by using electrification in the industry. Second industrial revolution lasted to 1970s, then, third industrial revolution started by operation of electronics and IT for automation of production. After all, today, we are mentioning about Industry 4.0, because it is on the basis of cyber physical systems. Technology and its applications which are used in Industrial fields have been changing in time. Kurfuss (2014), describes all Industrial revolutions processes. It states that first industrial revolution was driven by the advent of steam engines being used to power production facilities. Second industrial revolution was driven by the assembly line, exemplified by Henry Ford a century ago. Third industrial revolution, which occurred in the 1970s, was driven by the use of computers in production. For instance, the use of CNC machines, computer processing of quality and logistics information, were transformed during the 3rd industrial revolution. Valdez et. al (2015), describes Industry 4.0 is a paradigm shift in manufacturing technology.

It is seen that there have been carried out some studies within Industry 4.0. European Parliament (EP) (2016), Industry 4.0 was initially coined by the German Government. Stock and Seliger (2016), presents an overview of different opportunities for sustainable manufacturing in the scope of Industry 4.0. Germany Trade & Invest (2017), states that “Industry 4.0” or “Smart Industry” refers to the technological evolution from embedded systems to cyber-physical systems. It also represents the coming fourth industrial revolution on the way to an internet of things, data and services. EP (2016), states that Industry 4.0 has main features. These are “Interoperability, Virtualisation, Decentralisation, Real-Time Capability, Service orientation and Modularity”.

Figure 2. Technologies of Industry 4.0 (TÜSİAD, 2016)

The elements of Industry 4.0 are the cloud, additive manufacturing, augmented reality, big data and analytics, autonomous robots, simulation, horizontal vertical system integration, the industrial internet of things and cyber-security. Industry 4.0 has nine advanced technological products and already some of them have been using in manufacturing.

Rüßmann et. al (2015), But it can be said that with Industry 4.0, those given technologies transform production: isolated, fully integrated, automated and optimized production inflow; changing traditional production relationships among producers, and customers and suppliers between human and machine. Although there have been created some studies which integrates both STEM Education and Industry 4.0, it can be seen that they are not enough. It is also known that some of them are not directly linked to each other. Flynn (2012), investigated the relationship between STEM principles for advanced manufacturing education. West (2012), examined that how Australian universities could be best prepare STEM graduates in the scope of in the academic researches and economy. Landivar (2013), investigated the relationship between science and engineering education and employment in STEM occupations. SIEMENS (2017) investigated in its study, the relationship between STEM and Industry 4.0 and it was highlighted them importance of STEM in integrating Industry 4.0. When we focus on both Turkish STEM Education situation and Industry 4.0, it is seen that there have been prepared some reports and studies by private institutions and public institutions. TÜSİAD (2014) prepared a report, it highlighted the importance of STEM Education for future, within STEM Education and its relationship with Industry. Ministry of National Education (2016), states the significance of STEM Education within the scope of future jobs.

STEM Education and Industry have been paid attention to provide people having 21st century's skills. At this point, it is very important to focus on Turkey's situation on Industry 4.0 and STEM Education. It has been seen that there have been carrying out some studies which have been creating both by public and private institutions. However, it is also seen than these studies are not enough and it has not affected STEM Education system in Turkey. A report conducted by Turkish Ministry of National Education (MEB, 2016), also highlighted similar views. It states that STEM Education should be more considered for the future of Turkey and should also be integrated with Industry. European Comission (2016), vocational and training is precious for feeding job-specific and and transversla skills, fascilating the transition to employment and maintaining and updating the skills of the workforce.

World Economic Forum (2017), several countries in the Middle East and North Africa region have also been investing in technical and vocational education and training (TVET), notably Egypt and Turkey, although this particular form of education remains under-used across the region. There can be seen some studies related to Turkey's current situation on its education system and workforce. Turkish Industry and Business Association (2016), estimated that growth targets will be realized, in this context, the need for labor employed in industry will increase and also this labor force will be more skilled. Turkey Scientific and Technological Research Institution (2016), states that challenges of Turkey within smart technology are "need for higher skilled labor force, premature de-industrialization and low export share of high-tech products." World Economic Forum (2017), quality of Turkey's education system is under Word Average

(3.8) and potential impact of job automation may be challenging. It is estimated that 52% of all work activities are susceptible to automation.

There are some international exams carried out such as PISA, TIMSS, PIRLS. PISA is an international important exam since countries are able to see their position their current situation within science, math and reading. PISA is carried out every three years (OECD, 2017). To be able to understand Turkish students' skills in science, math and reading, PISA 2015 scores are important indicators for the educators and policy makers and it gives concrete evidences to link between current STEM Education and Industry in Turkey. Some countries' PISA 2015 scores are given in table 1.

Table 1. PISA 2015 Results of Top Five Countries and Turkey

	Science	**Math**	**Reading**
1.Singapore	556	564	535
2.Japan	538	532	516
3.Estonia	534	520	519
4.China (Taipei)	532	542	497
5.Finland	531	511	526
OECD Average	**493**	**490**	**493**
Turkey	**425**	**420**	**428**

According to PISA 2015 results, Turkish students' science test average was 425; math average was 420 and reading test average was 428. It can be seen that Turkish students' scores within those mentioned subjects are under PISA averages (OECD, 2016). Turkish students' math, physic, chemistry and biology test scores are not expected level in a national examination which is called "Examination of Bachelor Placement". Turkish fourth grade high school students' math average is 10.38 (under 50 questions); physic average is 5.48 38 (under 30 questions); chemistry average is 10.56 38 (under 30 questions) and biology average is 8.5 38 (under 30 questions) (ÖSYM, 2016). It is able to be said that Turkish students cannot transfer their knowledge within those subjects into their life. This result also means that many of Turkish students have not had 21st skills. Due to these given reasons the study can be said it is an original study which have not been studied yet.

So, it also promotes academic studies which are directly linked both STEM Education and Industry 4.0. After all, aim of the study is to investigate the current situation of STEM education and Industry 4.0 in Turkey.

The Data of the Study

The data of the study were taken both international and national references such as articles, reports, doctoral dissertations and statics of Turkish Education System and Turkish Industry System. The obtained data from Ministry of National Education's studies and reports and from other ministries, international exams' reports and results gave very important knowledge for the study.

In this study the data were analyzed through document analysis. Within this context, 191 articles were investigated within STEM education, 16 articles were investigated within Industry 4.0. 25 doctoral dissertations were looked into which were prepared based on STEM education and totally nine international reports were investigated within STEM education and Industry 4.0.

Table 2. The Data of the Study

	PhD Dissertation	Articles	Reports	Books	Total
STEM Education	25	191	9	3	228
Industry 4.0	-	16	8	1	25
STEM Education and Industry 4.0	-	5	2		7

The data of the study is given in table 2. The finding of this study have been obtained based on these studies that are already given in table 1. According to the table 1, totally 260 academic studies were investigated and analyzed to create of the data of this study. Including academic studies carried out at national and international level, both national public institutions and private institutions' report were considered, as well.

What Have Been Found?

As mentioned previously, STEM studies have been increasing in Turkey. Although this result, it is not enough for a Turkish education system since Turkey has 80 million populations and it has to be ready for Industry 4.0. It is claimed because Turkish students' science, math and reading achievements are not at expected level. It can be seen by looking at both national and international exams' results such as PISA, TIMSS and TEOG. There are some indicators which help us to understand the current situation of STEM Education in Turkey.

By looking at the data which has include top 1000 high school students' choice the placement of STEM fields can help us to understand the position of STEM fields choice in Turkey.

All engineering fields, computer sciences, mathematical sciences and scientific fields have been included in STEM fields jobs. Medicine sciences have not been included in STEM fields. National Science Foundation (NSF), which is the great association and supports STEM fields, also do not include Medicine into the STEM fields (NSF, 2015). In figure 1, it can be said that the STEM fields placement have been changing and it has a wave.

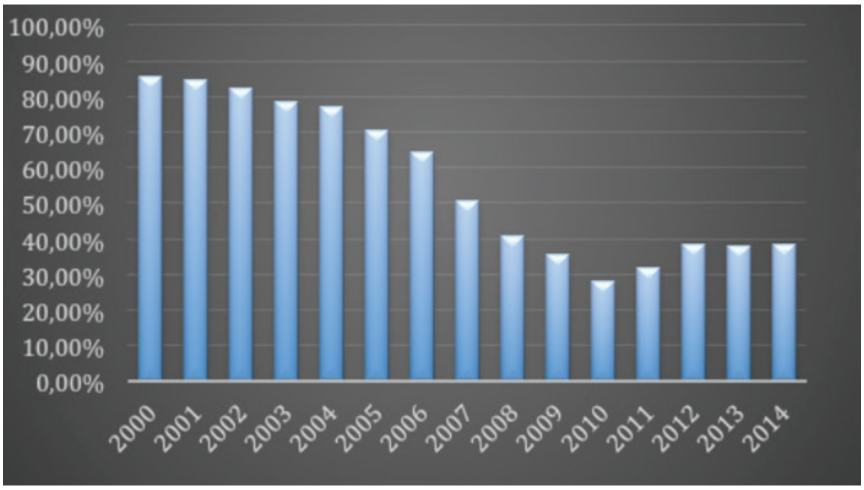

Figure 3. The Ranking Placement of Top 1000 Students in STEM Fields Within SSPC (Student Selection and Placement Center) Akgündüz et al (2015),

It is seen that the STEM placement was 85.63 % in 2000; 27.88 % in 2010 and 38.23 % in 2014. The choice of STEM fields career have been tried to be promoted in USA and European Countries, within this scope there were set up some STEM organizations and associations both in USA and in EU. Those organizations create some STEM projects which aim to get students toward STEM fields. It is expected that having 21st century skills for a society or country will be very important to conduct Industry 4.0. The skills of 21st century are "critical thinking, effective problem solving, innovation, creativity, team working, communication and collaboration". This result shows us there must be taken necessary precaution in STEM fields choice and it is also necessary to encourage STEM career. There is a report that confirms results which are given in the figure 3.

World Economic Forum (2017), stated in its report that the World Economic Forum's Future of Jobs analysis had found that by 2020, 21% of core skills in the countries of the Gulf Cooperation Council and 41% of those in Turkey are going to be different compared to skills which were needed in 2015.

Vocational high schools and technical high schools are important organizations for Turkey so that they support industrial firms' labor. We have some interesting results of students, who have studied in an industrial vocational high schools. Within the scope of LYS 2016. According to results, 40.225 students participated to this exam and their both math and science average was 160,98, while Anatolian's high school students average was 221.785 and science high schools students' average was 360.409 (ÖSYM, 2016). There are some international studies which are focused on Turkey's industrial organizations.

King of Netherland (2017), found some findings on the awareness among Turkish companies regarding Industry 4.0 and it reveals that 22% of the companies have extensive knowledge, 59% has general knowledge and 19% have no knowledge about such developments.

This result is similar with ÖSYM's results of vocational students' in Turkey. Because, vocational students' 21st skills are important for Turkish future Industry to have much more quality within Industry 4.0. It is unfortunately seen that Turkish vocational high school students' achievements are not located at desired level. At this point, an international study carried out by OECD (2009), can be given to support previous results of the study.

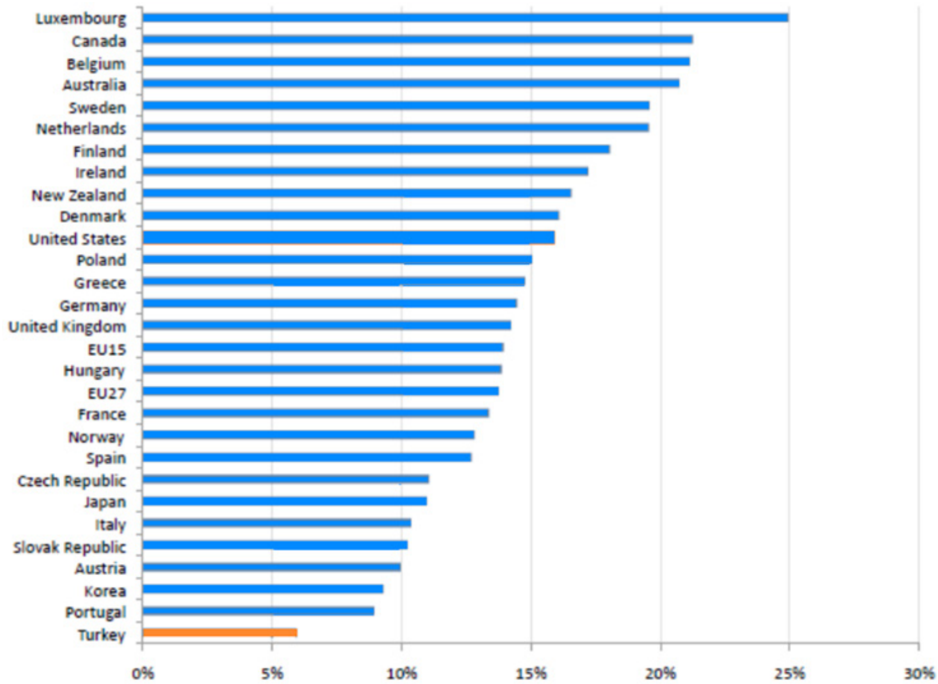

Figure 4. Share of Workforce in Science and Technology Occupations (2008)

The share of workforce was investigated in a study carried out by OECD (2009), it presents us to understand share of the workforce in science and technology occupations among 30 countries. It is seen that Turkey is located at the end of the ranking within share of the workforce in science and technology occupations. This result is seen that is suitable within Turkish students PISA 2015 scores in science and math.

Another important indicator within current STEM Education situation in Turkey is STEM organizations and their studies. Turkish universities must have important roles to promote STEM Education and to link between STEM Education and Industry. It has been found that there have been created some STEM centers in some Turkish universities. It has been understood that there are four STEM centers which were created by four universities. The first of it was set up in 2014 in a private university. When we focus on business sector's efforts for STEM Education within Industry 4.0, it is able to be said that TÜSİAD has conducted some studies which are related STEM Education and Industry 4.0. In its first report (TÜSİAD, 2014) on STEM Education, it portrays a frame for the STEM Education. Actually in all these studies, TÜSİAD tries to reveal the current situation of STEM Education and what will be done to promote Industry 4.0 in the future for of Turkey.

There are some national public organizations that they prepare reports and publish articles and they launch some calls on Industry 4.0. The Scientific and Technological Research Council of Turkey (TÜBİTAK) is one of guide, which has launches many calls, publish studies and support both public and private national institutions within the scope of STEM Education and Industry 4.0. TÜBİTAK (2016), reveals that there have been carrying out some workings within Industry 4.0 which we can understand it via its Tenth Development Plan. The tenth development plan defines those strategic features:

*Qualified people and strong society,

* Production based innovation, high growth with sustainability,

* Livable places and sustainable environment,

* To have development providing international cooperation

We are able to understand by looking at those features that those given features already present the aim of STEM Education and presents 21st century's workforce. It can also be claimed from this plan that if desired Turkey has a strong Industry in the future, Smart Industry or Industry 4.0, Turkish people have to have those features.

King of Netherlands (2017), TÜBİTAK prepared a roadmap within Industry 4.0 for Turkish Industry. It is defined that technology is devoted three groups following: "Digitalization, Connectivity and Future factories". In this roadmap, the content of Industry 4.0 are framed very well. There have been stated some highlights on advanced manufacturing in TÜBİTAK's national call for 2016 and 2017; Additive Manufacturing: Multilayer additive manufacturing, Rapid prototyping and 3D printing Technologies, CAD/CAM, simulation & modelling software, Robotics and mechatronics, Flexible manufacturing. Within the scope of Internet of Things, it is emphasized Sensors and sensing systems, Virtualization, M2M communication and Cloud computing.

All those given applications are included in ındustry 4.0. It has been found that there is no model that it reveals the relationship between STEM Education and Industry 4.0. To link between STEM Education and Industry 4.0, it is given a model, it has been created by the author, which explains the relationship between STEM Education and Industry 4.0

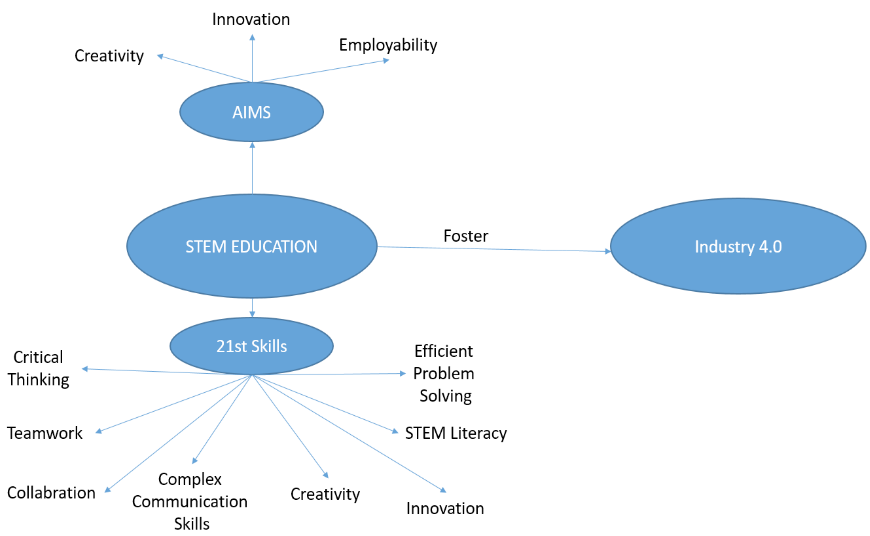

Figure 5. A Model That Shows the Relationship Between STEM Education and Industry 4.0

In this model, it is seen that STEM Education fosters Industry 4.0 with its aims and 21st skills. It can be understood from the model that STEM Education should be enhanced to have high quality industry for a country, this can be claimed especially for the Turkey. Some 21st skills and STEM Education's aims are very important to have high quality Industrial System within Industry 4.0. Another significant indicator is to link STEM Education's aims and 21st skills. Within this context, they are necessary to be linked to STEM Education so STEM Education can foster Industry 4.0.

Conclusion

In this study, it has been focused on to set up the relationship between STEM Education and Industry 4.0 and within this scope to define the relationship and current situation in Turkey. It has been reached that Turkish education system must consider the role of STEM Education to reach Industry 4.0. PISA 2015, TIMSS 2015 and LYS 2016 results within science, math and reading fields have showed us that Turkish students are not placed at expected level among other countries in terms of achievement of these fields (OECD, 2016, ÖSYM 2016). Killingsworth (2014), states that industry certificate is necessary into a skilled-level position in a technology or engineering field.

Gonzales (2010), revealed in his study how global economy motivated both federal and state governments with private industry to enhance the improvement of STEM academies. Lars, et al. (2015), state that the manufacturing industry has been continuing to be a central driver of growth for economies worldwide and in the Industry 4.0 concept, it is necessary for workers make themselves ready for the new fields of modern smart manufacturing. Boyd & Tian (2016), reveals that capable workers, who have expertise in

STEM, are deemed main fort he researches and development activities which stimulate economic growth. In Turkey, there are many STEM Centers, which claim that they donate students with 21^{st} skills and give STEM Education. As mentioned in the previous section that most of them actually do not give STEM Education and it is already clearly seen that they are not able to give those educations due to their lack of competent in STEM Education. Atkinson & Mayo (2010), state that producing more and better STEM graduates is going to require new institutions; especially new specialty science high schools and new kinds of programs and even colleges at the BS level.

Although there have been carrying out some limited studies, projects, it is seen that vocational technical high schools are not supported sufficiently within STEM Education and Industry 4.0. Vocational high school students should be supported to create new projects linked to STEM Education and Industry 4.0' fields, especially. There are some studies related this study. Hughes (2013), states in her study that partnerships with industry may be strong enough opportunities for students to investigate fields of STEM disciplines. Kerr (2013), both industry and education are key pieces in the STEM puzzle.

The integration STEM Education with Industry should be provided to have much more skilled people, who are equipped with 21st century skills, in 21st century. It can be given an example that is directly related do this statement. The Guardian (2016), revealed in its news that Australian high school students made a drug to treat malaria disease. In the process, it was understood that they have collaboration, team working, effective communication, critical thinking, innovative approaches, entrepreneurship. Besides it has been understood by the news that students could manage to produce the medicine cheaper than other medicines, which are already used by people. This means students' medicine can support employability for people in the future manufacture.

Recommendations

*STEM Education studies should be organized by Ministry of National Education and Turkish Universities in collaboration. It means all STEM studies can be carried out professionally at national level.

*STEM centers could be found and STEM experts can be provided to work in these centers. They can be supported with real STEM materials which are linked with Industry in order to make a real STEM Education and to donate students with 21^{st} century's skills.

*The relationship between vocational high schools and Industry should be carried out by using STEM Education and its applications to reach Industry 4.0' features.

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