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TÍTULO: La identificación de competencias STEM de estudiantes de Ciencias Técnicas.

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RESUMEN: El estudio realizó un análisis de datos para identificar las competencias profesionales claves para la educación STEM que son esenciales para los estudiantes jóvenes que tienen una educación especial en ciencias técnicas. El presente artículo se basa en tres objetivos: elaborar un concepto detallado de STEM que se base en habilidades blandas, de liderazgo e inteligencia emocional, explorar la importancia de las habilidades de liderazgo en el sistema educativo STEM y desarrollar el método tradicional de gestión con El nuevo método que se basa en el principio de la inteligencia emocional. Por último, para todos, los hallazgos del artículo ayudan a ambos sectores, tanto educativo como corporativo, a comprender la importancia de STEM.

PALABRAS CLAVES: análisis de datos, intelecto emocional, liderazgo, competencias STEM, educación STEM.

TITLE: Identifying STEM Competences of Technical Sciences students.

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ABSTRACT: The study conducted data analysis to identify key professional competencies for STEM education that are essential for young students who are particularly educated in technical sciences. The present article is based on three objectives: to elaborate a detailed concept of STEM which is based on soft, leadership and emotional intelligence skills, to explore the importance of leadership skills in the STEM education system, and to evolve the traditional method of management with the new method that is based on the principle of emotional intelligence. Last, to all, the findings of the article help both sectors, educational as well as corporate in understanding the importance of STEM.

KEY WORDS: data analysis, emotional intellect, leadership, STEM competences, STEM education.

INTRODUCTION.

In the era of the Fourth industry revolution (4.0), the world is continuously evolving at a fast pace (awareness regarding technology and technological complexities) which creates a massive impact in daily life. People's demands, as well as their choices, are also changing from time to time.

Numerous organizations are indulging technologies in their organization and change their traditional methods because the era of the 4.0 revolution brings more technological support due to which different industries get assistance in their growing and development phase. Besides this, the objective of altering the traditional model is achieved by implementing various methods and technologies, such as individual learning, flexible environment, applying formal and informal educational methods, development of the placements and international scientific centers.

In most of the developing countries such as the US, Australia, the UK, Canada, Japan, Israel, etc., the concept of STEM education is consistently growing. The growing ratio shows that they apply the integrated approach in their education system, where concepts related to science and technology are discussed by relating their daily lives. An integrated approach provides benefits to the countries such as the development of the strong educational system, through this, students can learn variety of skills and become the STEM specialist and in future also get the chance to become the employer's choice (Guyotte et al., 2014; OECD, 2016; Gunn, 2017).

The concept of STEM was first originated by R. Colwell, an American scientist in 1990 and later the 20th century everyone is aware of the word STEM. Additionally, after STEM, two other concepts also raised, the first one is STEAM (science, technology, engineering, art, and math) and the second is STREM (science, technology, robotics, engineering, and math) (Catterall, 2017; Gunn, 2017).

The term STEM is considered as an important concept because it does not only support the liberal arts but also diversifies the entire quality of the education system. Additionally, by merging science and humanity with arts, educational institutions can raise students who possess a variety of skills and knows how to think creatively. Secondly, it also helps the students to enhance their knowledge and skills so that they can use in their professional career (Kegan, 2001; Abadzi, 2015).

In today's world, employers found that STEM graduates do not possess essential skills due to which they do not get the chance of employment. The reason is that the educational system focuses on communication skills rather than STEM education (Kautz et al., 2014; OECD, 2017; McCarthy, 2019). Because of these issues, most of the developed countries adopted STEM education such as the USA. Additionally, it is also found that various educational systems consider liberal arts as a necessary element and now providing equal importance to arts along with science and humanities (Earnest, 2015).

Various institutions implemented STEAM education; the examples are highlighted below:

- At the post-secondary level- the Massachusetts Institute of Technology (MIT) offered certification in STEAM along with the introduction of STEM courses.
- At the secondary level- Concordia High-school included STEAM principles in their curriculum to increase the interactivity of students (Gunn, 2017).

In 2011, President Barack Obama also discussed the STEM education concept and communicated that this system brings technological enhancements in the country and allow the US to remain competitive all over the world. President also quoted that the government should also invest in the STEM education system and offer various scholarships in a variety of subjects so that every student can get the chance of supporting their families by doing jobs (National Technology Leadership Coalition, 2009).

In the previous article, it is highlighted that the US and Canada also invested in educational projects to support their economy such as they developed “academic communities”. This new concept helps the educational system in increasing the competencies of the students and trained them for the corporate life (Watson & Groh, 2001; Stoll et al., 2006).

According to the report published by WestEd and the National Committee on Teaching & America's Future found that including STEM courses in the educational system increases the percentage of potential students because these courses help them to learn professional environment along with the development of KSA (Knowledge, skills, and abilities) (Choi, 2006).

It is also found that multinational firms want to hire those who have leadership skills, or sometimes these organizations offer training programs to existing employees to improve their skills. Moreover, most of the organizations required STEM specialists, therefore, various institutions consider STEM principles an essential step in improving the quality of the education system:

- Offered STEM courses along with management and leadership courses
- Add separate portfolio of STEM proficiency and a model of leadership in line with STEM.
- Provide training to the leaders regarding the STEM to enhance the skills of generation Z
- Apply various methods while implementing the STEM education that also emphasizes on developing economies.

These objectives show significant issues in the current educational system and highlighted the importance of the STEM education concept.

DEVELOPMENT.

Methods.

Research Design.

To fulfill the objective of the study and to investigate a new model of STEM education and its competencies, the first stage is to examine the factors of STEM along with its importance in the education system.

The latest STEM education programs are based on two principles that are teamwork and group project. The key idea behind this program is to train students to develop problem-solving skills and to improve their analytical skills in the field of math and engineering. The model is currently used by various countries such as the EU, the USA, and Canada.

It is found that in the US most of the educational system follows an integrated approach at all stages (from kindergarten to postgraduate). The key accomplishment is to develop a balance between science and liberal arts (Sanders, 2012).

The latest STEM education is based on two factors, problem-based teaching (PBT) and problem-based learning (PBL). PBT is defined as the enhancement of teaching abilities at the post-secondary and secondary level, whereas PBL is based on the coordination of students and teachers (Gunn, 2017). These factors PBT and PBL assist students to discover, summaries, observe and analyze ideas, then share and discuss opinions. Here the teacher plays the role of a facilitator who is responsible for helping students by defining them the differences and similarities (OECD, 2017).

Furthermore, problem-oriented learning assists students to observe things and understand the differences in professional and daily routine environment. It also supports students to implement the ideas with creativity either individually or in a group. Students are also bound to obey the norms developed by the facilitator (OECD, 2017).

STEM courses with the components of PBL and PBT are taught to students so that they can able to think independently and creatively. Additionally, the activities are assigned to each student that is based on learning activities. These activities help students to understand from experiences (Gorman, 2019).

According to American Next Generation Science Standards (NGSS), students are required to adopt various competencies, these are discussed below (Achieve Inc, 2013; Abadzi, 2015):

- Identify issues and positing questions.
- Developing and implementing models.
- Evaluating and interpreting data.
- Implementing math in resolving computing issues.
- Doing debates and provide logical solutions.
- Analyzing the quality of information.

These standards are developed by combining various competencies that are based on 8 scientific and technological practices (Achieve Inc, 2013).

Secondly, there are other competencies as well related to STEM which is defined by the International Society for Technology in Education (ISTE) (2007). However, these standards are also the same which is explored by NGSS. According to ISTE, most significant qualities for STEM professional are:

- Innovation and Creativity.
- Cooperation and communication.
- Research methods and data analysis.
- Decision making, problem-solving and analytical thinking.

- Digital thinking.
- Formulation.

Additionally, the basic standards related to Math's (Common Core Standards Initiative, 2015) and the Technological Literacy (International Association of Technology) also displays the main competencies of STEM, these are:

- Evaluating problems and resolve them insistently.
- Analytical and logical thinking.
- Providing effective criticism.
- Development of mathematical algorithms, model and structure.
- Formation of strategy.
- Aware of technological and sociological knowledge.
- Design.

The basic goal behind all these standards is to increase the ratio of STEM professionals. According to the principle of science-art combination, STEM education is a pure and balanced integration of technologies and humanities.

Thus, to develop a comprehensive model of STEM competencies, it is also essential to explain leadership skills along with the operational skills.

The latest and unique method that helps future leaders to understand the competencies well is through the acmeological approach. Firstly, it created numerous educational terms, out of these terms "professional invariant" is one of them which is defined as, basic professional capabilities, being independent and flexible in the working environment (Guyotte et al., 2014; Kautz et al., 2014). The second term is known as "auto-psychological competence" which is defined as the development of enthusiasm which assists in dealing with duties (Schoon et al., 2015).

According to acmeological principles, management becomes sustainable when leaders develop the skill of "professional invariant" and could deal with complex situations effectively.

Besides this, by reviewing all the defined standards and principles related to STEM education, the presented study emphasizes on the New Public Management (NPM) as it is considered as the most significant concept of STEM. The basic principles of NPM are independency of educational institutions, educational institutions can operate as marketization, diversification, clear formation of educational procedures along with maintaining the quality.

By combining STEM methodology with the NPM principles, it established the following standards such as:

- Decentralization in the HR and Finance departments.
- Implementation of unique models related to educational systems and based on suitable price and quality.
- Development of a flexible management system.
- Creating a strategic alliance among government and private education sector.
- Provide training to future leaders to enhance the capabilities of human resources.

Data Analysis.

As it is mentioned in various studies as well as in the current study, it is essential to implement or include STEM because of the technological advancements and the demand of the employers. According to gathered data, in the EU the ratio of STEM professionals has increased with 12% during the year 2000-2013. Moreover, it is also predicted that in Europe the demand for STEM professionals will grow with a ratio of 8%. However, professionals from other fields will be increased by 3%.

The report presented by the Organization for Economic Co-operation and Development (available on OECD website in the Graduates by field of education section) (Stats.oecd.org, 2019), found that in the future the world, as well as employers, demands three professionals and these are engineers, designer, and architect.

As it is mentioned in Table 1 below, the data of 26 countries are gathered from the report of OECD form the year 2012. USA and Japan are founded as a huge number of STEM graduates. It is also found that South Korea is also at a similar percentage of STEM graduates. However, according to the analysis it is also observed that European countries are comparatively below from the three mentioned countries (USA, Japan, South Korea).

France, Germany, Poland as well as the UK displayed the massive number of STEM graduates in Europe, though it is relatively low than the USA and Japan. By analyzing all the percentages, it is also observed that the percentage of STEM graduates is growing each year. The analysis shows that various countries are now transforming their educational system by applying the concept of STEM education. Lastly, it is also analyzed that internationally, the demand for STEM professionals is increasing.

Apart from this, at the same time, the overall technological advancement shows a fall in the technical specialist from all over the world. The issue of each country is distinct from each other; however, the fall is more recognized in Asia. According to the report conducted by OECD related to the global shortage, found that 81% of the Japanese organizations (with more than 10 staff members) deal with the challenges while hiring the qualified personnel (see the attached figure below).

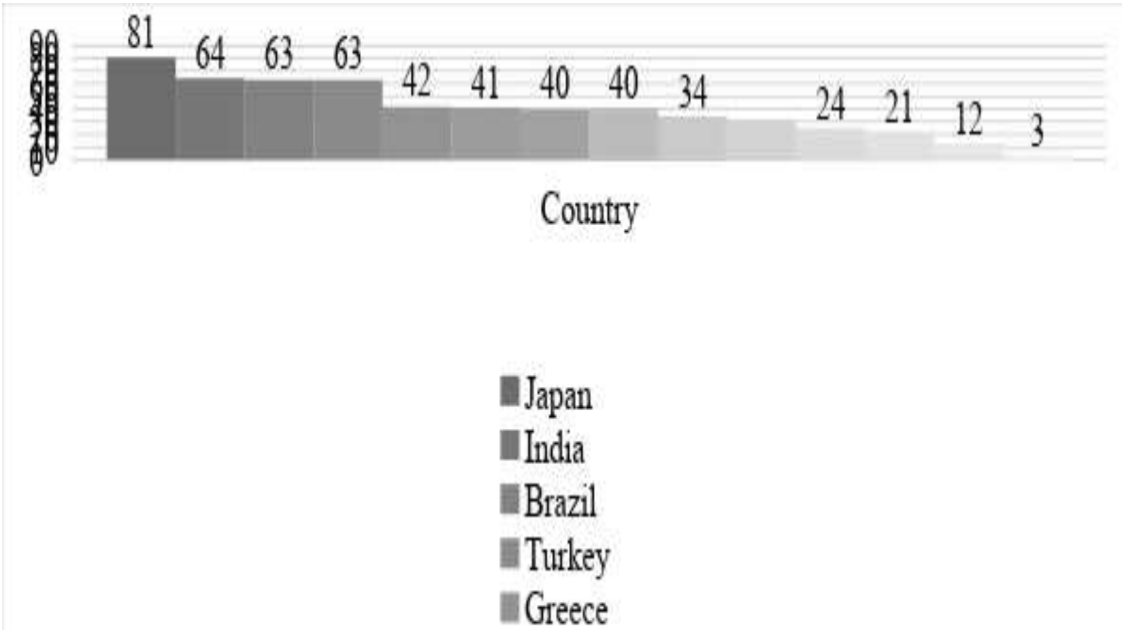

Figure 1. The countries with the highest shortage of STEM specialists, 2016.
Source: Statista portal (McCarthy, 2019).

The shortage of personnel globally is one of the highlighted topics on the forum of World Economic (WEF) from the last previous years. For example, 45% of STEM professionals who are currently working, interviewed by OECD in which they stated that they found themselves lack of basic or essential skills due to which they are not able to work effectively and efficiently. From these specialists, only 3 out of 10 feel that they possess required and competent skills that help them to deal with complexity at the workplace. These problems are also identified in Mexico, Japan, and Korea.

Table 1. The proportion of STEM-graduates (engineering, design, construction, architecture) in countries during 2003-2012. Source: www.stats.oecd.org 2019.

Year Country	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
Australia	13997	14686	16502	16898	16866	16923	..	19087	20702	..
Austria	3581	3606	3601	3910	4464	4787	..	6422	7131	7479
Belgium	4179	4386	4320	4574	7948	7276	..	8745	8905	9229
Canada	..	13865	17343	17556	17793	19132	19094	18838	18542	19631
Czech Republic	6900	7643	8177	9793	11864	13719	13361	14112	13344	12756
Denmark	3518	3770	4117	4123	5141	4917	..	4740	5393	5904
Finland	7967	8093	8324	8364	8638	9080	9257	12223	10157	10706
France	51302	51302	55240	54474	55037	55055	54088	0	0	0
Germany	35761	36206	38135	39276	41956	45958	49978	56438	65804	73536
Greece	0	1874	4270	5717	4342	5562	..	5585	5511	5598
Hungary	5062	4562	4582	4131	4506	4466	5637	6101	6528	7275
Italy	37846	49744	56428	56518	55322	34953	34269	32719	56208	47853
Japan	133111	130707	131417	130986	130900	129570	128195	123673	125021	126545
Korea	81797	82204	82763	79622	79472	92392	89916	89385	95391	93764
Netherlands	9590	8693	8940	9691	9476	9510	9900	10314	10803	12519
New Zealand	1683	1899	2071	2273	2281	2711	2849	..	3353	3728
Norway	2462	2521	2421	2486	2584	2702	2835	3370	3727	3820
Poland	36110	34144	36387	42564	46328	47102	50686	55655	65336	66363
Portugal	8739	7094	7531	8187	14695	17489	15004	14407	15377	16634
Slovak Republic	4831	5177	6074	5975	6813	8644	9812	9855	9358	9481
Spain	32689	31391	29490	29060	29036	30204	33087	36109	46368	42344
Sweden	9372	11061	9660	10230	9202	8925	8868	9996	11331	11711
Switzerland	3603	3722	4394	4778	5387	5070	5471	5462	5892	6506
Turkey	19234	20003	21513	21918	23756	26333	28249	28806	28574	31583
United Kingdom	41568	..	43240	45347	46011	48237	49476	55763	60081	61237
United States	127073	133914	136637	138134	138231	142717	147788	153426	162649	170972

In the year of 2013, European organizations also faced difficulties in the hiring of STEM professionals who has the greatest competencies. The ratio that has been identified is almost 40%. It is the most prominent issue which is identified in the organizations and the information is also exhibited in the OECD report in the year 2013.

Numerous employers quoted that the main issue behind the shortage of labor is lack of training, creativity, and analytical or logical thinking.

Most of the educational system focuses on other skills that are entirely different from computer skills and because of this people are not comfortable in using technologies and this also delays their involvement in numerous activities. The report conducted by the "Future of Jobs" stated that the skills that are considered necessary in 2016 will be diminished by 2020 (World Economic Forum, 2016).

Analyzing the international trends and by seeing the ratio of talent shortage globally, the change will bring larger influence in terms of increasing ratio of STEM specialists particularly in developing countries.

The study conducted by the National Science Foundation found that in the previous 10 years the percentage of STEM professionals in the US has grown three times against the number that are currently highlighted.

It is also predicted that the percentage of STEM professionals will be raised by 1.7% as compared to other sectors, which is estimated at 9.8%. By viewing these increasing ratios, the US government donated funds to the educational system to transform their traditional education system to the STEM educational system ($ 206m – in 2012 budget) (OECD, 2017; 2017b).

At the same time, in the year 2013, the plan related to Federal Educational system was approved and various principles were set by the government that is based on three statements, provide training to the “new generation” facilitators, increase the salary of the existing teachers and lastly, create awareness and promote in order to attract more students towards the STEM educational system.

In other countries, the government also support STEM education at large scale such as:

- In Finland, the government took initiative and developed the LUMA Centre. The LUMA Centre plays an essential role in providing facilitation and cooperation among schools and universities. Secondly, it also assists in developing educational materials for students related to STEM.
- In Malaysia, the government established three-step STEM education reform. This reform is for teachers who receive training and learn various educational methods. Secondly, it promoted the STEM educational system through social media campaigns. Thirdly, the reform becomes a bridge among the first two steps to proceed with the latest programs and methods.
- In Australia, the National STEM School Education Strategy was accepted. The objective of this strategy is to enhance the entire quality of the STEM educational system during the year 2016 to 2026.

Furthermore, in Europe (Austria, Germany, France, Italy, the Netherlands, Norway, the UK, Ireland, Spain etc.) variety of projects related to STEM education was established for example «In Genius» (2011-2014), «MASCIL» (2013-2016), «INSTEM» (2012-2015), «Mind the Gap!», «ER4STEM». All programs are working on the same objective that is to improve the quality of secondary school education by eliminating the gap among the theory and practice. The second aim of these programs is to reduce gender inequality and raise funds to support financially.

Results.

By analyzing the methodology of explored the STEM education model, it is concluded that the STEM education system is an effective system that assists in raising the professional competencies. The below table demonstrates the progress of STEM competencies during the year 2015 to 2020.

Table 2. Top 10 skills in STEM in 2015 and 2020.

No.	2015	2020
1.	Complex Problem Solving	Complex Problem Solving
2.	Coordinating with Others	Critical Thinking
3.	People Management	Creativity
4.	Critical Thinking	People Management
5.	Negotiation	Coordinating with Others
6.	Quality Control	Emotional Intelligence
7.	Service Orientation	Judgment and Decision Making
8.	Judgment and Decision Making	Service Orientation
9.	Active Listening	Negotiation
10.	Creativity	Cognitive Flexibility

Source: Future of Jobs Report, World Economic Forum.

According to the above table, complex problem solving is considered a highly essential competency of STEM. However, critical thinking is shifted from the 4th to the 2nd stage and becomes an essential competency. It is also observed that the greater changes in these competencies table are relevant to creativity because it is shifted from the 10th stage to the 3rd. Lastly, it is also studied that in the era of 2020 the skill related to emotional intelligence will be highly demanded by managers and it will replace active listening.

The second most important factor in STEM is gender inequality. The research which was published in the World News & World Report obtained that according to the US STEM Index, the percentage of women who received the STEM education is increased by 15% during the past five years.

The interest of females in STEM was decreasing from last year (see Figures 2-3). The reason is that numerous women who are working in STEM organizations are facing discrimination due to which they are doing more efforts to increase their abilities to compete in the male dominant society. Additionally, most of the females who are working in the STEM organization quoted that they faced gender inequality issues at the workplace.

To reduce the issue of discrimination, females are required to enhance their skills in STEM as well as also required to develop leadership and emotional intelligence skills. It is also found that females are more emotional as compared to men, therefore, the highlighted competencies help in developing a successful career.

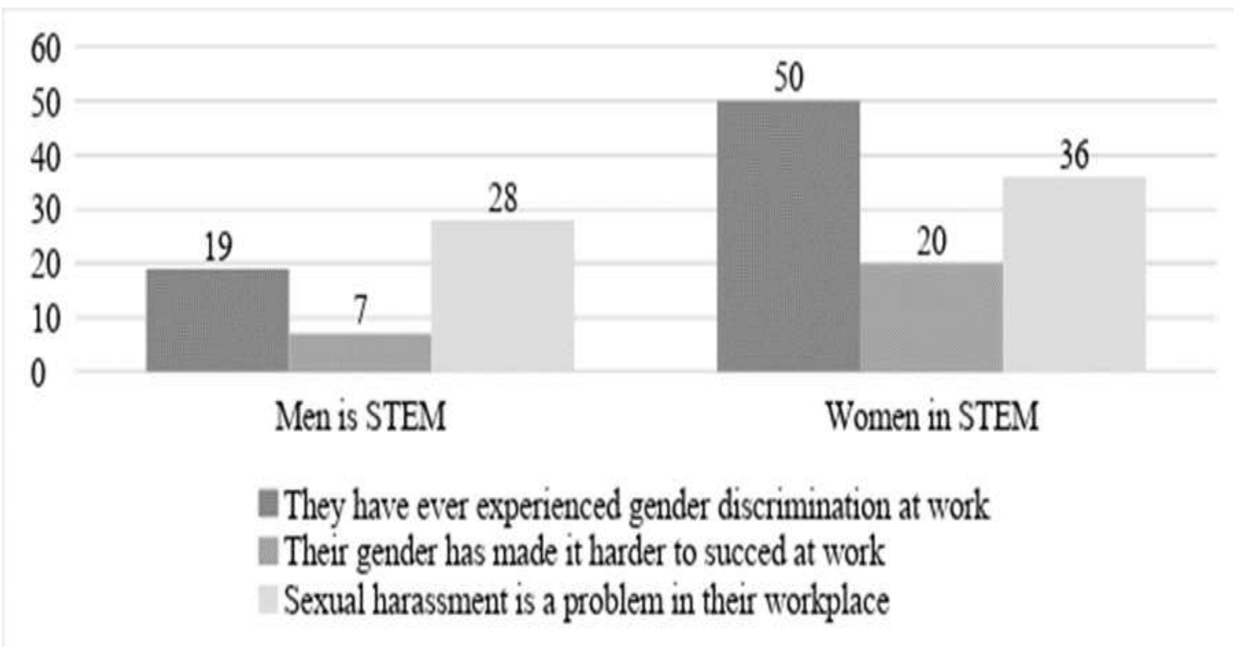

Fig. 2 Gender problems in the STEM industry, 2016, %.

Source: Survey of U.S. adults conducted July 11 – Aug. 10, 2017.

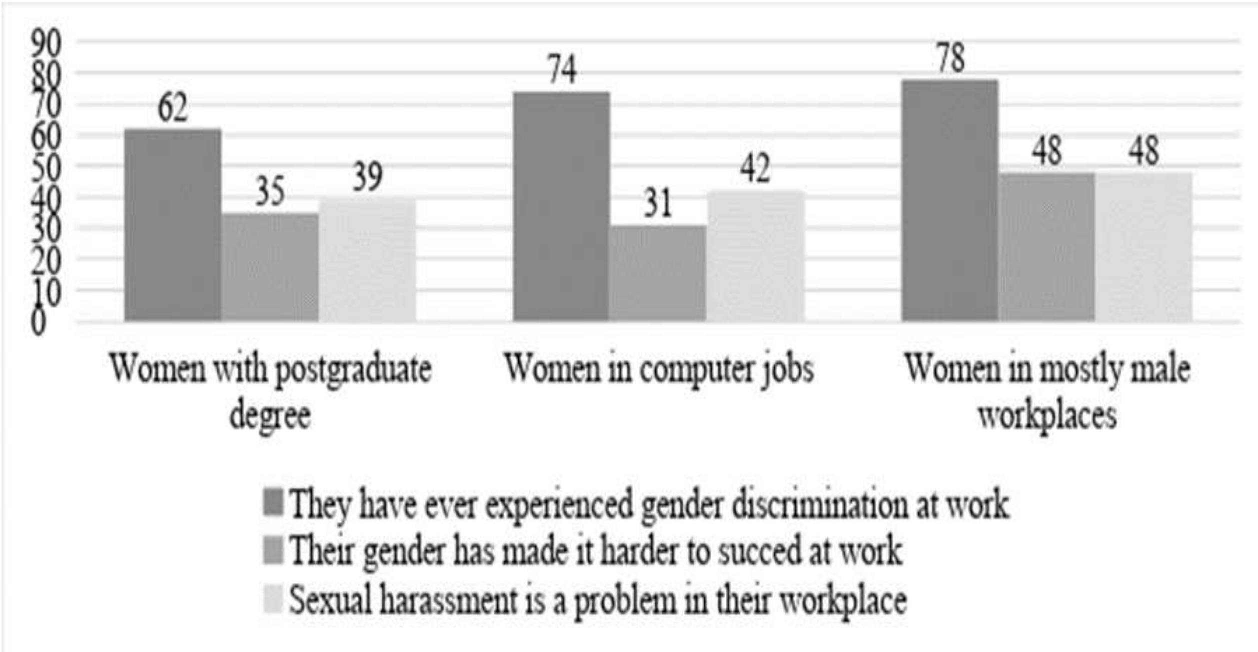

Fig. 3 Women in STEM jobs - the degree of qualification, 2016, %.

Source: Survey of U.S. adults conducted July 11 – Aug. 10, 2017.

There are other STEM competencies as well, which is defined by the Global STEM Alliance (the New York Academy of Science) (Global STEM Alliance, 2018).

The study displayed the accurate classification of knowledge, skills, and abilities for STEM professionals. The defined competencies of STEM are classified into two components, Essential Skills and Supporting Attributes, these are presented below:

Table 3. Two main clusters of STEM competence.

No	Essentials skills	Supporting attributes	Brief description
1.	Critical Thinking	Essential Skills	A skill that is used to evaluate various information, evidence as well as material. Identify appropriate materials and identify accurate information to support the evidence.
2.	Problem Solving	Essential Skills	A skill that helps in developing a rabe of solutions related to STEM-based issues. It also covers ideas, goals and implementation plans.
3.	Creativity	Essential Skills	A skill that raises inner abilities in which a person solves various problems even their problems with unique solutions.
4.	Communication	Essential Skills	An ability to communicate effectively and clearly so that everyone can understand the concept of STEM topics. Additionally, the implementation of both formal and informal approaches.
5.	Collaboration	Essential Skills	Get a chance to participate in group projects. Here facilitator and students are required to discuss, plan and execute together.
6.	Data Literacy	Essential Skills	An ability to engage with quantitative and qualitative data to resolve various problems.
7.	Digital Literacy & Computer Science	Essential Skills	Concepts related to computer science are combined with STEM concepts when it is appropriate (e.g., as part of problem-solving, critical thinking, and logic-based reasoning). Digital literacy skill is needed when technology tools are used.
8.	STEM Mindset	Supporting Attributes	STEM mindset is a skill where students predicted a variety of solutions with an open mind and come up with innovation (e.g., empiricism, design thinking, mathematical proof) and explore STEM dispositions (e.g., curiosity, objectivity, flexibility).
9.	Agency & Persistence	Supporting Attributes	Provide a range of time to resolve the issues and for thinking about new approaches to overcome the obstacles.
10.	Social & Cultural Awareness	Supporting Attributes	Consider cultural practices while implementing STEM concepts in the working environment and society, particularly related to international citizenship and international STEM issues.
11.	Leadership	Supporting Attributes	To get the role of leaders to practice leadership skills. It is associated with taking initiatives, communicate clearly and gaining trust.
12.	Ethics	Supporting Attributes	Awareness of ethics is also a part of the STEM specialist's work and its principles.

Source: (Global STEM Alliance, 2018).

Though, without highlighting the importance of competencies that are showed above, a detailed STEM portfolio cannot be accomplished without the competencies of leadership. It is also considered the milestone of the corporate world.

The new approach of leadership is different from the traditional theory of management, which is defined as people are preoccupied, and consider that for motivating employee’s skills are not needed. The new definition of leadership is to maintain trust among the leaders and the employee. In line with this definition, STEM leaders possess the following competencies:

- Productivity – shaping the work process constantly, to attain goals with existing resources.
- Flexibility – Ability to adapt change and ready to share ideas with subordinates.
- Technological awareness – the ability to adopt new technologies such as SMM.
- Time-management – invest time in solving complex problems.
- Teamwork – distribute the work equally among the teams and individuals to achieve a high level of productivity.
- Emotional Leadership – the capability of understanding other person's emotions without hurting anybody.
- HR Skills – recruitment, selection, development of staff and provide training to staff.
- Social Skills – formation of information links vertically as well as horizontally, providing feedback, public speaking, develop a supportive working environment.

Discussion.

One of the important questions in the new educational system is whether STEM has replaced with STEAM. The argument related to the STEAM educational system is that creative skills can be applied in any field from science to politics. Though the efficiency of the educational system does not depend on the curriculum, it is also depending on converting the environment into positive and creative (Playfoot & Hall, 2009; Smith-Barrow, 2014; Schoon et al., 2015).

Additionally, various scientists and educational systems assume traditional STEM concept as the outdated concept. Hence, science and math are taught in one curriculum and engineering and technology are taught separately and this creates a huge gap between the theory and practice. Secondly, math and science courses are limited because of standardized testing while engineering and technology are offered in the curriculum in the form of specialization (Watson & Groh, 2001; Stoll et al., 2006; Williams, 2011).

Other arguments are also raised that STEM methodology must be applied from starting school and continue to college and university. Professionals from the US stated that it must be applied from the school and offered to students in college and university as a specialization course. However, European specialists believe that advanced STEM courses should be taught at the tertiary level (ISTE, 2007; Williams, 2011; OECD, 2017; Gunn, 2017).

In line with the concept of STEM leadership education, there are two schools of thought that are different from each other. Motivational theory is the first school of thought, which is defined as the ability of a leader who motivates employees financially and supports them in developing professional skills etc. This theory is different from the theory of values which is based on the principle of earning revenues and this is the only goal for the managers as well as for employers. In this theory, motivation is not considered as the priority (Blumenfeld et al., 1991; Atkinson & Messy, 2012; Kautz et al., 2014).

Another definition is given by the humanist school of thoughts (R. Blake, G. McGregor) stated that every individual could be organized, take initiative, and take responsibility, and the ultimate objective of the management is to provide support to every individual.

The rule of considering individual needs is based on the theory of acmeological as it is defined as viewing the personal growth of employees.

Lastly, to increase the awareness of STEM it is essential to include robotization specialists in human activity as it also creates better opportunities for generation Z.

CONCLUSIONS.

The analysis and results generated by evaluating the data related to the modern STEM education system are highlighted below:

- The acmeological theory used to train STEM professionals is considered as one of the main concepts for modern STEM competency system.
- The traditional method used in the education system must be evolved and integrated with a practice-oriented model such as providing training services to the facilitators.
- The third and the highly essential point is that it is necessary to include communication and leadership courses to prepare students for becoming STEM specialists so that they can use their capabilities in the educational sector as well as at the corporate level.
- The designed competence portfolio of STEM can be considered as an effective model and can be used by the various educational system. The reason is that it helps the students to learn a variety of skills.
- The discussed standards and principles related to the STEM education system, courses, competencies as well as different concepts related to the school of thought can be implemented by educational institutions nationally as well as internationally.

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