Professional Competences in STEM Education

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Fairuza Sabirova (✉)
Kazan Federal University, Yelabuga, Russia
fmsabir@mail.ru

Marina Vinogradova
Russian State Social University, Moscow, Russia

Anastasia Isaeva
Tula State University, Tula, Russia

Tatiana Litvinova
Sechenov First Moscow State Medical University, Moscow, Russia

Sergey Kudinov
RUDN University, Moscow, Russia

Abstract—The ongoing changes in the modern world - represented with nano-, bio-, info- and cognitive technological development - requires a certain skill set, mastering of which is necessary for any professional and above all - a STEM-specialist. Thus, alongside the technological advancement, leading global corporations seek to employ candidates exhibiting particular soft-skills, among which leadership and emotional intellect are in especially high demand. The purpose of the article is to formulate a comprehensive STEM portfolio, consisting of soft, emotional and leadership skills (SELS). Consequently, a new method of developing leadership skills in the STEM educational process is offered. As opposed to traditional methods of management, the new approach is based on the principle of emotional intellect, thus allowing to influence employees on a level that engages them personally, hence more effectively. The offered methodology is applicable in both educational and corporate spheres of professional STEM activity.

Keywords—STEM education; emotional intellect; competences in STEM; leadership; data analysis.

1 Introduction

In the age of the Fourth Industrial Revolution (Industry 4.0) our world is constantly transformed by the rapid flow of information and innovative technology impacting every sphere of our life. The needs of society continually change, and so does our personal interest. The paradigm of Industry 4.0 implies complete robotization of industry with the help of computers, programmed to model every stage of production:

from planning and developing products and services to marketing and management strategies. This process influences the traditional educational models so that they can serve as a reliable stepping stone for future specialists, preparing them for a digitalized world. This goal is achieved by applying specific methods and technologies, such as personalized learning, establishing creative co-working spaces, integrating formal and informal education, creating university hubs and international scientific centers.

As of today, in most developed countries - the US, Israel, Australia, the UK, Japan, Canada etc. - the popularity of STEM-education grows invariably. It represents an integrated approach to education, whereby all scientific and technological concepts are taught in the context of everyday life. The aim of this approach is to build a sustainable educational progression between school, university and work, and to ingrain a deeper understanding of global economy so that the future STEM-specialist is in step with modern labor-market demands [1], [2], [3].

The acronym “STEM” was first offered by the American scientist R. Colwell in 1990s, and began to be utilized actively at the dawn of 20th century. Subsequently, two modifications of the term were offered: STEAM (science, technology, engineering, art and math) and STREM (science, technology, robotics, engineering and math) [3], [4].

It’s worth mentioning that the original concept of STEM is congruent with liberal arts in a way that not only diversifies education, but also enhances its overall quality. By merging science and humanities, this model of education paves the way for creativity and personal development of students. In this system, future specialists are taught to use their creative thinking on par with logic, which harmonizes their integration in the economy of Industry 4.0 [5], [6].

Yet, employers note that modern-day STEM graduates lack social skills which hinders their ability to work as a part of a team. The reason for that is the tendency of colleges and universities to overlook interpersonal communication skills, hence leaving it to the future employers [7], [8], [9].

However, this doesn’t impede the ever-growing popularity of STEAM-education, which continues to soar in its country of origin - the USA. It is becoming obvious, that numerous educational institutions on all levels see liberal arts as a vital part of the curriculum, assigning same importance to science and humanities [10].

Thus, the most prominent examples of successfully implementing the STEAM system are:

- *At the tertiary level* - the Massachusetts Institute of Technology (MIT) which provides specialized courses in STEAM, as well as multiple orientational courses in STEM
- *At the secondary level* - Concordia High-school, where the curriculum is based on the STEAM principle and implemented via increased interactivity [3].

In 2011, President Barack Obama in his address to the Congress described STEM-education as a forward-looking method of technological innovation in the US, which would allow the country to remain competitive in the face of global economic tendencies. The governmental support of teacher education in the sphere of STEM was reaffirmed by the provision of numerous grants in this field [11].

One of the latest STEM-education projects in the US and Canada is the creation of what is commonly referred to as "academic communities". Their introduction into the school system has proven to be an effective means of ameliorating the working environment [12], [13]. From reports by WestEd and the National Commitee on Teaching & America's Future, it is apparent that teaching STEM increases the number of potential students by motivating the applicants with professionally organized academic communities and interactive learning environment [14].

It is also a well-known fact that leading global corporations seek either to employ potential leaders or to develop leadership skills in existing employees. For the most part, it concerns STEM organizations, therefore we consider the application of the following principles a vital step in improving the quality of technical education:

- Teaching STEM-subjects together with leadership and management courses
- Developing a full portfolio of STEM competences and a new model of leadership in the sphere of STEM
- Adapting the model of training STEM leaders to the needs and capabilities of generation Z (millennials)
- Defining methods for enhancing state STEM education in the context of advanced and developing economies

These goals represent the main educational problems in the modern STEM discourse, and represent a roadmap of educational reform.

Table 1. Specifications table

Subject area	**Education, STEM education**
More specific subject area	STEM education, professional competences
Type of data	tables, figures, text files
How data was acquired	Statistal portals, OECD, Future of Jobs Report, World Economic Forum
Experimental factors	Data analysis was conducted regarding the key professional competences vital for young specialists educated in technical sciences (maths, mechanical engineering, biotechnology, construction etc.)
Data accessibility	Data is with this article

2 Methods

2.1 Research design

To reach the main objective of the study - to develop a new model of STEM competences - we must first analyze the specificities of the overarching STEM concept, as well as its implementation in the system of state education.

The modern STEM educational programmes are founded on the principles of teamwork and project-group work, where one of the main goals is to offer innovative ways of problem-solving and to sharpen critical thinking in the framework of maths and engineering. This model of education is widely used in the EU, the USA and Canada.

In the US the integrative approach to teaching is a common practice on all educational levels - from kindergarten to postgraduate - where the main achievement is considered the balance between science and liberal arts.

Speaking generally, the modern STEM education consists of two components - problem-based teaching (PBT) and problem-based learning (PBL).

The concept of PBT represents a method of continually improving the skill set of teachers working on both secondary and tertiary educational level.

Whereas PBL is based on professor-student cooperation with the view to solve real-life problems within an educational setting [3]. In such a setting, students explore, gather and analyze ideas; then, while sharing them, they make predictions and debate with each other. The teacher’s role is to facilitate the learning process by directing the debate and helping students to formulate pertinent questions [8].

Ultimately, problem-oriented learning helps students to think in a way they would think in a professional environment, to apply their knowledge to solving specific problems individually and in a group setting, even though the students are moderated and have to conform to certain norms established by the teacher [8].

In the context of PBL and PBT, STEM subjects are taught in a way that prompts initiative and independent thinking. The tasks offered to a student require the usage of yet unknown learning activities, thus motivating them to learn from experience [15].

The main competences that a student needs to acquire can be represented as follows, by quoting the American Next Generation Science Standards (NGSS) [6], [16]:

- Positing questions and defining problems
- Developing and utilizing models
- Planning and researching
- Analyzing and interpreting data
- Applying maths in solving computing problems
- Providing logical arguments in debate
- Assessing the quality of information

The present standardization is the result of merging competences pertaining to 8 scientific and technological practices [16] (see Appendix F).

There is an alternative classification of STEM competences, designed by the International Society for Technology in Education (ISTE) [17]. The following standards - being somewhat similar to the ones listed above - focus on technological skills, which - in the view of the ISTE - are crucial qualities for any STEM professional:

- Creativity and innovation
- Communication and cooperation
- Data analysis, mastery of research methods
- Critical thinking, problem-solving, decision-making
- Digital thinking

- Conceptualization

Apart from that, the Common Basic Standards in Maths [18] and the Technological Literacy standards (International Association of Technology) offer yet another view on what constitutes the main competences in the sphere of STEM:

- Acknowledging problems and solving them persistently
- Thinking abstractly and quantitatively
- Offering valid criticism
- Building mathematical algorithms and models, structurizing
- Developing strategy
- Possessing comprehensive technological and sociological knowledge
- Design

The common aim of all mentioned standards is to ensure a steady professional growth of a STEM specialist. Based upon the principle of science-art integration, the core of STEM education is a balanced combination of technology and humanities within one curriculum.

However, in order to build a comprehensive model of STEM competences, it is also necessary to define what constitutes leadership in relation to previously mentioned operational skills.

The newest approach to teaching future leaders is considered to be the acmeological approach. First and foremost, in introduces several educational terms, one of them being "professional invariant" which can be defined as "basic professional abilities, independent from the outside factors of the work environment" [1], [7]. The second key term is "auto-psychological competence" - "readiness to develop personally in order to fulfill certain tasks" [19]. Thus, according to acmeological principles, successful management is only possible when the leader's skills have evolved to the point of "professional invariant" and are flexible enough to solve problems under pressure.

Regarding the application of the mentioned principles in a state educational system, the author of the present study considers the concept of NPM (New Public Management) to be the most adequate for STEM. The main postulates of NPM are: autonomy of educational institutions; marketization of state educational institutions, their diversification; harmonization of the educational process and the control of its quality.

Upon integrating STEM-methodology with the concept of NPM, it becomes possible to deduce the following principles:

- Decentralization of resource control in HR and finances
- Applying innovational models of educational services based on an adequate price/quality ratio
- Creating a flexible management system
- Forming a strategic alliance between government and private sector
- Training a new generation of leaders, enhancing the potential of human capital

2.2 Data analysis

As already stated, owing to rapid technological development, new occupations emerge in various fields of professional activity, including STEM. For instance, in the EU the number of employed STEM professionals has grown by 12% during the 2000-2013 period. It is expected that in Europe the demand for technical specialists will grow by 8%, while the demand for specialists from other spheres will increase only by 3%.

The global statistics on STEM-graduates - as of 2012 - is presented by the Organisation for Economic Co-operation and Development (available on OECD website in the Graduates by field of education section) [20], concerning the professions most commonly associated with STEM - engineer, designer, architect.

As we can see in the table below, by 2012, among 26 countries covered by the OECD study, USA and Japan demonstrate the highest number of STEM-graduates. South Korea is almost at the same level, while the European countries find themselves considerably below the three leading positions. France, Germany, Poland and the UK exhibit the highest number of STEM-graduates in Europe, although it is still 2.5 times less than in USA and Japan. However, it is important to note that in all the countries the number of STEM-graduates grows with each year. This can attest to their shared strategic interest in STEM education, as well as the increased demand for STEM specialists on the global scale.

At the same time, overall rapid technological development caused a shortage of technical experts in all parts of the world. The magnitude of the problem differs with each country but is more pronounced in Asia. According to the OECD report on global labour shortage, 81% of Japanese companies (with more than 10 staff members) face challenges in finding qualified personnel (see the figure below).

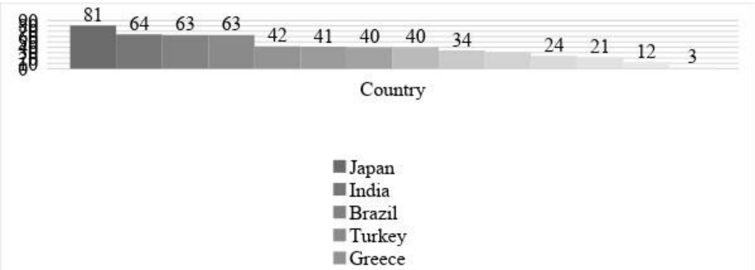

Fig. 1. The countries with the highest shortage of STEM specialists, 2016

Global change in professional spheres has been one of the key topics on the World Economic Forum (WEF) last several years. Meanwhile, 45% of working STEM-professionals questioned by the OECD, consider themselves lacking relevant skills, mastery of which would help them work more efficiently. Only 3 out of 10 believe their skillset is sufficient for dealing with work challenges at all degrees of difficulty. Such problem has also manifested itself in Mexico, Japan and Korea.

Table 2. Proportion of STEM-graduates (engineering, design, construction, architecture) in countries worldwide over time (2003 -2012)

Country Year	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Australia	13 997	14 686	16 502	16 898	16 866	16 923	..	19 087	20 702	..
Austria	3 581	3 606	3 601	3 910	4 464	4 787	..	6 422	7 131	7 479
Belgium	4 179	4 386	4 320	4 574	7 948	7 276	..	8 745	8 905	9 229
Canada	..	13 865	17 343	17 556	17 793	19 132	19 094	18 838	18 542	19 631
Czech Republic	6 900	7 643	8 177	9 793	11 864	13 719	13 361	14 112	13 344	12 756
Denmark	3 518	3 770	4 117	4 123	5 141	4 917	..	4 740	5 393	5 904
Finland	7 967	8 093	8 324	8 364	8 638	9 080	9 257	12 223	10 157	10 706
France	51 302	51 302	55 240	54 474	55 037	55 055	54 088	0	0	0
Germany	35 761	36 206	38 135	39 276	41 956	45 958	49 978	56 438	65 804	73 536
Greece	0	1 874	4 270	5 717	4 342	5 562	..	5 585	5 511	5 598
Hungary	5 062	4 562	4 582	4 131	4 506	4 466	5 637	6 101	6 528	7 275
Italy	37 846	49 744	56 428	56 518	55 322	34 953	34 269	32 719	56 208	47 853
Japan	133 111	130 707	131 417	130 986	130 900	129 570	128 195	123 673	125 021	126 545
Korea	81 797	82 204	82 763	79 622	79 472	92 392	89 916	89 385	95 391	93 764
Netherlands	9 590	8 693	8 940	9 691	9 476	9 510	9 900	10 314	10 803	12 519
New Zealand	1 683	1 899	2 071	2 273	2 281	2 711	2 849	..	3 353	3 728
Norway	2 462	2 521	2 421	2 486	2 584	2 702	2 835	3 370	3 727	3 820
Poland	36 110	34 144	36 387	42 564	46 328	47 102	50 686	55 655	65 336	66 363
Portugal	8 739	7 094	7 531	8 187	14 695	17 489	15 004	14 407	15 377	16 634
Slovak Republic	4 831	5 177	6 074	5 975	6 813	8 644	9 812	9 855	9 358	9 481
Spain	32 689	31 391	29 490	29 060	29 036	30 204	33 087	36 109	46 368	42 344
Sweden	9 372	11 061	9 660	10 230	9 202	8 925	8 868	9 996	11 331	11 711
Switzerland	3 603	3 722	4 394	4 778	5 387	5 070	5 471	5 462	5 892	6 506
Turkey	19 234	20 003	21 513	21 918	23 756	26 333	28 249	28 806	28 574	31 583
United Kingdom	41 568	..	43 240	45 347	46 011	48 237	49 476	55 763	60 081	61 237
United States	127 073	133 914	136 637	138 134	138 231	142 717	147 788	153 426	162 649	170 972

Source: OECD [20]

In 2013, 40% of European employers reported difficulties in finding STEM specialists with an accomplished skill set. Predominantly, this was an issue in the enterprise sector, which was reflected in OECD reports of that time.

Thus, according to the employers, one of the main problems is the lack of creativity and critical thinking - the only skills that cannot be simulated by a computer, in the age of ever-evolving technology, which renders human involvement unnecessary in multiple activities. According to the "Future of Jobs" report presented on the Forum, more than one third of skills considered important in 2016 will change by 2020 [21].

In response to the global labor market tendencies, the change will be largely influenced by the increased demand for STEM professionals, especially in developed countries. According to the study by the National Science Foundation, in the last ten years the number STEM workplaces in the US has grown three times the number of those in other spheres of economy. It is estimated that the number of STEM workplaces will increase by 17 % in contrast to the 9.8 % increase in other sectors. This is one of the reasons why the US government allocates considerable funds to STEM educational programs and institutions ($ 206m - in 2012 budget) [8], [22].

Along the same line, in 2013, the Federal STEM education plan was approved, thus obliging the government to train several thousands of “new generation” teachers, to raise the wages of the existing ones and to increase the number of students majoring in STEM disciplines.

The tendency to support STEM education was also demonstrated by numerous other countries:

- In Finland, the LUMA centre was founded in order to facilitate cooperation between schools and universities, as well as to develop educational materials for students majoring in STEM
- In Malaysia, a three-step STEM education reform was launched, envisaging in-service training of school teachers while implementing new educational methods; promoting STEM professions through media campaigns; producing a roadmap to coordinate the first two steps and proceed with advanced programmes and initiatives
- In Australia, the National STEM School Education Strategy was approved with the objective to improve the overall quality of STEM education during the 2016-2026 period

In Europe (Austria, Germany, France, Italy, the Netherlands, Norway, the UK, Ireland, Spain etc.) a range of projects launched: «In Genious» (2011-2014), «MASCIL» (2013-2016), «INSTEM» (2012-2015), «Mind the Gap!», «ER4STEM» - all directed towards enhancement of secondary school education by reducing the gap between theory and practice, overcoming gender inequality and reinforcing educational personnel financially.

3 Results

Upon analyzing the methodology of innovative STEM education, it may be concluded that the comprehensive system of competences serves as the foundation for the development of professional skills. The following table presents the potential evolution of key STEM competences during the 2015-2020 period.

As we can see, complex problem solving remains the most important STEM competence, while critical thinking has moved from 4th to 2nd position, thus becoming more relevant. The biggest changes in this rating are associated with creativity, which has climbed from the 10th to the 3rd position. It can also be observed that in 2020 the competence of emotional intelligence has emerged and replaced active listening.

Table 3. 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

Another important aspect of STEM education is the gender issue. According to the US STEM Index, published in the World News & World Report, the number of women who received a STEM degree has grown by 15% over the past five years. The female interest in STEM, however, began to decrease last year (see Figures 2-3).

As we see, the majority of women working in STEM-industry have experienced gender discrimination, which translated into applying more effort in the course of career advancement and establishing credibility in male-dominant collectives. In fact, most women employed in STEM industry claim they have experienced discrimination at some point in their career.

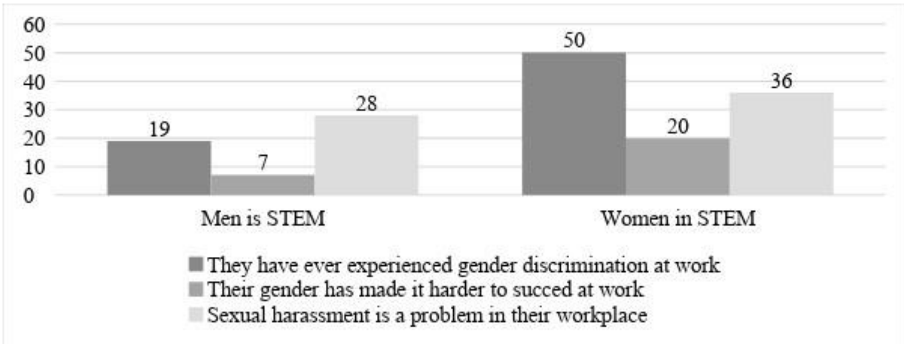

Fig. 2. Gender problems in STEM industry, 2016, % (source: Survey of U.S. adults conducted July 11 – Aug. 10, 2017)

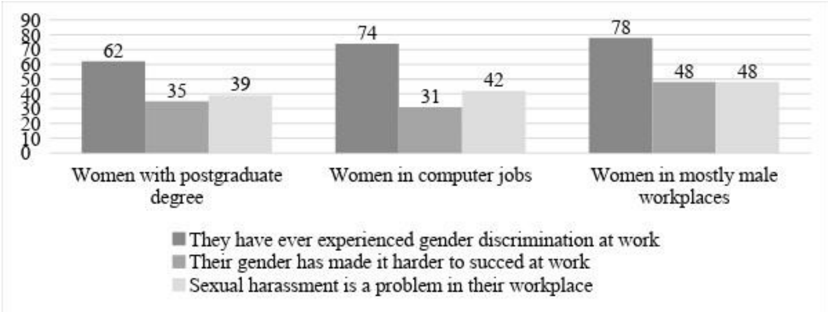

Fig. 3. Women in STEM jobs - the degree of qualification, 2016, % (source: Survey of U.S. adults conducted July 11 – Aug. 10, 2017)

In order to overcome these obstacles, female STEM-specialists have no other way, but to insert their ideas more proactively by mastering the competence of emotional leadership and emotional intellect. Taking into account the fact that women are generally more emotional than men, the mentioned competences will serve as a framework for successful career development.

Regarding the remaining STEM competences, we consider the study conducted by the Global STEM Alliance (the New York Academy of Science) [23] to be the most accurate categorization of knowledge and skills, indispensable for an advanced STEM specialist. The chosen competences were divided in two clusters - Essential Skills и Supporting Attributes and presented in the following table.

Table 4. Two main clusters of STEM competence

No	Essentials skills	Supporting attributes	Brief description
1.	Critical Thinking	Essential Skills	Skill to evaluate multiple sources of information, evidence, and primary material; select appropriate material to support arguments; critique the work of others; and differentiate evidence from inference and opinion.
2.	Problem Solving	Essential Skills	Skills to develop their ability to generate solutions to a range of STEM-based problems and scenarios, including organizing ideas, defining goals and milestones, and executing plans. Materials support the use and evaluation of a range of approaches to problem solving, including the scientific method and design thinking.
3.	Creativity	Essential Skills	Skill to approach problems from many different perspectives, including own. Novel approaches or solutions are explicitly valued.
4.	Communication	Essential Skills	Frequent and varied opportunities to practice and demonstrate ability to communicate clearly, accurately, and/or persuasively about STEM topics to multiple audiences, both formal and informal.
5.	Collaboration	Essential Skills	Frequent opportunities to engage in group work. Teacher and/or student supports are included to help students work together to plan, organize, and execute activities.

6.	Data Literacy	Essential Skills	Skill to engage with qualitative and quantitative data as part of analytical tasks such as problem solving, investigation, and design.
7.	Digital Literacy & Computer Science	Essential Skills	Computer science concepts are integrated into STEM content when appropriate (e.g., as part of problem solving, critical thinking, and logic-based reasoning). Skill of technology tools usage, the digital literacy skills needed to use the tools
8.	STEM Mindset	Supporting Attributes	Skill to approach problems with an open mind, consider a range of solutions, seek innovation, and express their ideas in a variety of modes. (e.g., empiricism, design thinking, mathematical proof) and productive STEM dispositions (e.g., curiosity, objectivity, flexibility)
9.	Agency & Persistence	Supporting Attributes	Possibility to allow adequate time for exploration of problem-solving approaches, setbacks, and adoption of new approaches as obstacles are encountered.
10.	Social & Cultural Awareness	Supporting Attributes	Skills to use cultural perspectives and address the value of social and cultural awareness, sensitivity, and empathy in STEM professional work and in society, especially as related to global citizenship and global STEM challenges.
11.	Leadership	Supporting Attributes	Possibility to get leadership roles and practice leadership skills. Skills such as taking initiative, building consensus, and communicating effectively in groups are needed.
12.	Ethics	Supporting Attributes	Knowledge of ethics as part of STEM professional work and its application.

Source: [23]

However, without derogating the importance of competences listed above, a comprehensive STEM portfolio cannot be completed without leadership competences - the keystone to success of any enterprise.

The new approach to leadership - as opposed to the traditional theory of management - is characterized not with the ability to ensure that everybody is preoccupied, but rather with a skill to motivate employees and inspire productivity. The backbone of modern leadership is, first and foremost, strategic thinking that requires trust and respect from those being led. In accord with that, we consider it appropriate that STEM leader portfolio includes the following competences:

Productivity - organizing the work process consistently, with the aim to achieve a certain goal with due regard for present resources, needs and priorities.

Flexibility - adapting to changes, to faultlessly switch projects, as well as the ability to share ideas and experiences with colleagues.

Technological awareness - effective usage of state-of-the-art technology, the capacity for SMM.

Time-management - investing time in solving prioritized problems rationally.

Team-work - distributing the workload adequately, taking into account each individual's skills and talents; creating a "synergetic" work atmosphere - that which is attributed with a high level of efficacy and profitability.

Emotional leadership (handling one's own and other people's emotions) - the ability to empathize and voice one's opinion thoughtfully, without undermining anybody's dignity; while still being able to achieve set goals.

HR-skills - allocating human resources, recruiting staff, taking into account their needs and potential career development; prompting their initiative; treating subordinates with regard to the value of their work.

Social skills - establishing information links vertically and horizontally, promoting feedback; public speaking; establishing the atmosphere of cooperation and mutual support.

4 Discussion

One of the main questions in modern educational discourse is whether STEM has to be replaced with STEAM.

The chief argument in favor of STEAM methodology is that creative skills are universally applicable in any domain - from science to politics. However, the efficacy of any educational system lies not only in a soundly structured curriculum, but also in its implementation, which has to make studying both enlightening and enjoyable [19], [24], [25].

In addition to that, many scientists and academics consider the traditional STEM concept to be lacking connection between the key subjects. Thus, science & maths from one side, and engineering & technology from another are taught separately, thus causing disparity between theory and practice. Maths and natural science programmes are limited considerably due to standardized testing, while engineering and technology are often offered to small groups of students in the form of electives [12], [13], [26].

There is also an academic disagreement on whether STEM methodology is to be applied starting from school, college or university. Specialists from the US deem it necessary to start complex STEM education from school with further specialization in college and university. While European experts believe that teaching advanced STEM should be conducted on the tertiary level exclusively [3], [17], [26].

With regard to STEM leadership education, there are presently two schools of thought opposing each other. One of them is motivational theory, based on the ability of a leader to stimulate effective work by motivating employees financially, ensuring they have ways to develop professionally etc. This approach is opposed by the theory of values founded on the principle of cash value maximization as the ultimate objective for a manager and a company as a whole. The proponents of this theory see the motivational aspect of management not as a priority but rather as a proxy for creating values [7], [27], [28].

Another perspective on leadership is offered by the humanist school of thought (R. Blake, G. McGregor) which stems from the assumption that every individual has an inherent capacity for self-organization, initiative and personal responsibility, and the ultimate goal of the management is to facilitate the realization of this capacity [5], [29], [30].

The policy of putting individual needs first makes this concept similar to acmeological theory of management, which is mainly based on expediting personal growth and personal worth of every employee.

Additionally, in order to uphold the trends of innovative STEM education, we deem it relevant to integrate the paradigms of technocrat and robocrat (robotization specialist) leadership in the light of ongoing robotization of every sphere of human activity.

Another development vector is shaping STEM education to needs and talents of the "millennials" and generation Z as the future basis of STEM labour market.

5 Conclusion

The results obtained in the course of analyzing modern STEM education tendencies point to the following:

- The acmeological approach to training STEM specialists is the overarching concept for the new STEM competence system;
- The old methodology must be reformed into an integrated practice-oriented model of education by introducing in-service training and preparing future teachers in the vein of student-oriented education;
- It is vital to teach communication and leadership skills in order to prepare STEM specialists who can be faultlessly integrated into a corporal collective;
- The offered competence portfolio can serve as a framework for future educational programmes, owing to the fact that it represents the expectations of future employers in the sphere of STEM;
- The mentioned educational standards can be implemented both nationally and internationally.

6 References

[1] Guyotte, K., Sochacka, N., Costantino, T., Walther, J., & Kellam, N. (2014). STEAM as social practice: Cultivating creativity in transdisciplinary spaces. Art Education, 67(6), 12-19. http://doi.org/10.1080/00043125.2014.11519293
[2] OECD (2016). Trends Shaping Education 2016. OECD Publishing, Paris. Retrieved from http://dx.doi.org/10.1787/trends_edu-2016- en
[3] Gunn, J. (2017). History and Evolution of STEAM Learning in the United States. Concordia University-Portland. Retrieved from https://education.cu-portland.edu/blog/classroom-resources/evolution-of-stem-and-steam-in-the-united-states/
[4] Catterall, L. (2017). A Brief History of STEM and STEAM from an Inadvertent Insider. The STEAM Journal, 3(1). https://doi.org/10.5642/steam.20170301.05
[5] Kegan, R. (2001). Competencies as working epistemologies: Ways we want adults to know. Defining and selecting key competencies. Hogrefe & Huber. Retrieved from http://www.voced.edu.au/content/ngv:18652
[6] Abadzi, H. (2015). Training the 21st-century Worker: Policy Advice from the Dark Network of Implicit Memory. IBE Working Papers on Curriculum Issues. Retrieved from http://unesdoc.unesco.org/images/0023/002355/235521e.pdf
[7] Daher, W., & Shahbari, J. A. (2020). Design of STEM Activities: Experiences and Perceptions of Prospective Secondary School Teachers. *International Journal of Emerging*

Technologies in Learning (iJET), *15*(04), 112-128. https://doi.org/10.3991/ijet.v15i04.11689

[8] Akimzhanova, M., Ilyassova, G., Nukusheva, A., & Rustembekova, D. (2018). Extendinglegislation of the Republic of Kazakhstan by anchoring international child rights. Journal of Legal, Ethical and Regulatory Issues, 21(3), 1-17.

[9] Tsalikova, I. K., & Pakhotina S. V. (2019). Scientific Research on the Issue of Soft SkillsDevelopment (Review of the Data in International Databases of Scopus, Web of Science). The Education and science journal, 21(8),187-207. (In Russian). https://doi.org/10.17853/1994-5639-2019-7-187-207

[10] Earnest, J. (2015). President Obama announces over $240 million in new STEM commitments at the 2015 White House Science Fair (fact sheet). The White House Briefing Room website. Retrieved from https://www.whitehouse.gov/the-press-office/2015/03/23/fact-sheet-president-obama-announces-over-240-million-new-stem-commitmen. https://doi.org/10.1016/j.repl.2015.01.037

[11] National Technology Leadership Coalition. (2009). Retrieved from http://ntlcoalition.org

[12] Watson, G., & Groh, S. (2001). Faculty mentoring faculty: The Institute for Transforming Undergraduate Education. The power of problem-based learning: A practical 'how to' for teaching courses in any discipline, 13-25. Sterling, VA: Stylus.

[13] Stoll, L., Bolam, R., McMahon, A., Wallace, M., & Thomas, S. (2006). Professional learning communities: A review of the literature. Journal of educational change, 7(4), 221-258. http://doi.org/10.1007/s10833-006-0001-8

[14] Choi, M. (2006). Communities of practice: an alternative learning model for knowledge creation. British Journal of Educational Technology, 37(1), 143-146. http://doi.org/10.1111/j.1467-8535.2005.00486.x

[15] Gorman, M. (2019). PBL STEM webinar. Retrieved from http://21centuryedtech.wordpress.com

[16] Achieve Inc. (2013). Next generation science standards. Retrieved from http://www.nextgenscience.org

[17] International Society for Technology in Education. 2007. Standards for students. Retrieved from http://www.iste.org/docs/pdfs/20-14_ISTE_Standards-S_PDF.pdf

[18] Common Core Standards Initiative. 2015. "Standards for mathematical practice." Retrieved from http://www.corestandards.org/Math/Practice/

[19] Schoon, I., Nasim, B., Sehmi, R., & Cook, R. (2015). The impact of early life skills on later outcomes. OECD (ed.). Second scoping group meeting on early learning assessment, OECD Publishing, Paris.

[20] Graduates by field of education. (2019). Retrieved from https://stats.oecd.org/Index.aspx?DatasetCode=RGRADSTY

[21] World Economic Forum. (2016). These countries are facing the greatest skills shortages. Retrieved from https://www.weforum.org/agenda/2016/07/countries-facing-greatest-skills-shortages

[22] OECD. (2017). PISA 2015 Results (Volume III): Students' Well-Being, PISA. OECD Publishing, Paris. Retrieved from http://doi.org/10.1787/9789264273856-en

[23] Global STEM Alliance. (2018). STEM education framework. The New York Academy of Sciences. Retrieved from https://cew.georgetown.edu/wp-content/uploads/2014/11/stem-execsum.pdf

[24] Playfoot, J., & Hall, R. (2009). Effective Education for Employment: A global perspective A report commissioned. White Loop Effective Education for Employment: A global perspective, Edexcel, White Loop. Retrieved from http://www.eee-edexcel.com/xstandard/docs/effective_education_for_employment_web_version.pdf

[25] Smith-Barrow, D. (2014). Recruiting the next generation of STEM employees. U.S. News and World Report. Retrieved from http://www.usnews.com/news/stem-solutions/articles/2014/04/28/recruiting-the-next-generation-of-stem-employees

[26] Williams, J. (2011). STEM education: Proceed with caution. Design and Technology Education: An International Journal, 16(1), 26-35.

[27] Pappas, M. A., Drigas, A. S., & Polychroni, F. (2018). An Eight-Layer Model for Mathematical Cognition. International Journal of Emerging Technologies in Learning (iJET), 13(10), 69-82. https://doi.org/10.3991/ijet.v13i10.8633

[28] Riaz, S., Rambli, D. R., Salleh, R., & Mushtaq, A. (2010). Study to investigate learning motivation factors within formal and informal learning environments and their influence upon web-based learning. International Journal of Emerging Technologies in Learning (iJET), 5(4), 41-50. https://doi.org/10.3991/ijet.v5i4.1338

[29] Buchholz, B., Shively, K., Peppler, K., & Wohlwend, K. (2014). Hands On, Hands Off: Gendered Access in Crafting and Electronics Practices. Mind, Culture, and Society, 21(4), 278-297. http://doi.org/10.1080/10749039.2014.939762

[30] Slykhuis, D., Madison, J., Martin-Hansen, L., Thomas, D.C., & Barbato, S. (2017). Teaching STEM Through Historical Reconstructions. The Future Lies in the Past – CITE Journal. Retrieved from https://www.citejournal.org/volume-15/issue-3-15/editorial/teaching-stem-through-historical-reconstructions-the-future-lies-in-the-past/.

7 Authors

Fairuza Sabirova has PhD in physics and mathematics. She is a Head of the Department of Physics. She is an Associate Professor at Kazan Federal University, Elabuga Institute, Elabuga, Russia.

Marina Vinogradova has MD degree in Economic Sciences. She is a Director of the Research Institute at Russian State Social University, Russia.

Anastasia Isaeva has PhD degree in Philological Sciences. She is an Associate Professor at Department of Foreign Languages at Tula State University, Russia.

Tatiana Litvinova has PhD degree in Pharmaceutical Sciences. She is a Head of the Department of Pharmacy at Sechenov First Moscow State Medical University, Russia.

Sergey Kudinov has MD degree in Psychology. He is a Head of Department of Social and Differential Psychology at RUDN University, Russia.

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