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STEM education (Science, Technology, Engineering, Maths) - Education for the future

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Abstract. *Understanding, recognizing and respecting norms, principles, values, and socio-cultural symbols are goals that the representative institutions of society aim to achieve through the active-participatory modeling of all children. Education, as a social action assumed at the level of the school unit, allows the acquisition of a statute and status by each person through his own effort, self-determination and commitment. The contemporary educational institutions, under the imperative of the transformations triggered by the technological revolution, are looking for appropriate answers to the challenges of society. An effective response is represented by the STEM educational concept based on the idea of educating students in four fields: science, technology, engineering and mathematics, using a multi-disciplinary and applied approach. The approach of STEM education and transdisciplinarity as a condition for the efficiency of educational action must be seen not only as an opportunity in the current socio-economic conditions, but also as a moral and professional obligation of teachers.*

Keywords: STEM education, transdisciplinary, interdisciplinarity, efficiency.

Theoretical framework

STEM education (Natural Sciences, Technology, Engineering, Mathematics) is an innovative approach in the educational process, which aims at transdisciplinarity and which is also a response to the challenges of the contemporary world. The transdisciplinary view of the world is based on the idea that "man is at the center of any civilization, and awareness of this can be a solution to the gap that precedes the decline of any civilization."[1]Transdisciplinarity differs from interdisciplinarity and pluridisciplinarity in terms of its outcome- understanding the contemporary society- an outcome that cannot be included in the disciplinary study. The purpose of interdisciplinarity and multidisciplinarity is always disciplinary knowledge. Under the circumstances of exponential growth of information, the volume of useful knowledge decreases, but what increases is the the minimum toolkit with which we process the facts we need. Therefore, instead of equating educational and scientific disciplines, there is a need for options for "integrated

[1] D'Hainaut L., Biancheri A.(1983). Des fins aux objectifs de l'éducation. Paris: Nathan, p. 232

cognitive fields" that transcend the boundaries between disciplines at levels that reveal intra-, inter-, multi- and transdisciplinarity.[2]

In the context of an emphasis on multi-, inter- and cross-cultural culture, cultural differences among various groups are accepted as natural and, moreover, beneficial to our spirit. "Some generations are born to create, others to maintain a civilization…. At present, in all areas of social life there is a need to create new forms, typical of the third wave"[3].

In an information and knowledge-based society, this concept highlights the pragmatism and contextualization of learning so necessary in the identification of valid solutions to the multiple problems that arise with increasing frequency. Confirmed in the EU's European Research and Innovation Program (2014) - "HORIZON 2020", focused on "building science skills"[4]. STEM education emphasizes the effective combination of science and technology based on connecting scientific knowledge to the real problems of society. Lifelong learning has become an accepted and assumed practice not only for the academic community, but for the whole European society.[5]

STEM is an educational concept based on the idea of teaching and instruction at both secondary and tertiary education levels focused on four pillars / fields, namely science, technology, engineering and mathematics in a multidisciplinary and applied approach, promoting a coherent learning paradigm based on applications from the real world. The contents are identifiable in the area of "new education", in an open context and in the background of complex problems that arise in contemporary society.[6]

The reference sphere of the STEM Education concept highlights the importance of scientific knowledge promoted by natural sciences (biology, physics, chemistry, physical geography, etc.), capitalized at the level of technology (socially applied science) and engineering (applied science in agricultural, industrial production , post-industrial, services, ICT-based, etc.), demonstrated and ordered mathematically and informatively (through the general and special theoretical and methodological resources of mathematics and informatics). Sorin Cristea (2020) appreciates that STEM education can be identified and confirmed as a:

- ✓ *Special type of curricular area,* achievable in formal, but also non-formal context, in secondary education (high school and vocational) and higher

[2] Lucian Ciolan, Transferable/transversal competencies, Education Center 2000+

[3] Toffler, A. (1983). The third wave, București: Politică Publishing House, p.594

[4] The European Commission. Proposal for a Council of Europe Recommendation on Key Competences for Lifelong Learning. Bruxelles, 17.01.2018.

[5] Council Recommendation of 22 May 2018 on key competences for lifelong learning. In: Official Journal of the European Union, 4.06.2018

[6] Manea, Adriana Denisa. "Educational values within the scope of the technological revolution", Astra Salvensis, VII, 14/2019, 31-37

education, in university studies aimed at broad specialization (bachelor's degree), in-depth (master's degree) and advanced (doctoral studies);

- ✓ *Pedagogical model of interdisciplinary, multidisciplinarity/ transdisciplinary* integration of theoretical (theoretical notions, axioms, laws, principles, formulas, essential data) and applied scientific knowledge (skills and abilities / cognitive strategies - problem solving and problem-based situations) supported attitudinally (affective, motivational, volitional, character) and axiologically, by permanent reference to the values of scientific truth (explanatory, experimental and demonstrative, logical-mathematical) and the usefulness of applied scientific truth (in social life, in production, in professional training, in the future evolution of the career);
- ✓ *Special scientific competence* based on the optimal use of three special types of knowledge or intelligence: a) experimental, "naturalistic" (proper to natural sciences) - b) applied (specific to technology as applied science and engineering, achieved by capitalizing on scientific knowledge in agricultural, industrial, post-industrial production, etc.) - c) logical-mathematical (proper to mathematical and computer sciences);
- ✓ *Particular pedagogical contents*, methodologically designed as a special answer to the issues of the contemporary world, affirmed in the open space of the "new education", related to the general pedagogical contents specific to scientific (intellectual) and technological education (applied science, professional, career counseling).[7]

Although the purpose of STEM education is realistic and necessary as it aims to encourage
educators to discover innovative solutions through a variety of options, one issue that occurs is the training of the teaching staff, of organizational awareness. The training of digital skills, both at the level of students and teachers, is the basis for success in addressing this type of education. "Just as teachers, whose tech-saviness comes as prerequisite in the teaching domain, need to adapt to the customised needs of their students, learners are also challenged by the multitude of sources, media and content to choose from. But, by working closely together and transforming the purpose of education into a mutual goal of self-development, the task of teaching-learning in the digital classroom turns into a more tangible one."[8] In

[7] Sorin Cristea, Educația STEM, in The Journal of Educational Theory and Practice Didactica Pro, 2020, doi.org/10.5281/zenodo.3692627

[8]Ioana Mudure-Iacob, "Digital Literacy: From Multi-Functional Skills to Overcoming Challenges in Teaching ESP," Astra Salvensis, VII /14, 59-70

STEM organizational culture reflects the general pedagogical values of scientific truth and the usefulness / efficiency / effectiveness of the socially applied scientific truth (through technology and engineering), which supports the design and development of a fully integrated and implemented STEM curriculum at the level of:

1) *Open pedagogical space,* which allows and stimulates: a) training focused on pedagogical innovation; b) learning through cooperation, in class, in groups and microgroups; c) integration of virtual learning environments; d) capitalizing on ICT in any context of teaching-learning-assessment; e) connecting to the professions of the future, determined by the evolution of STEM.

2) *Open pedagogical time,* towards: a) intradisciplinary, interdisciplinary, multidisciplinary,

and transdisciplinary projects; b) STEM training, pedagogically conceived as a teaching-learning-assessment activity, interdisciplinary, multidisciplinary, transdisciplinary; c) the special roles of the teacher - as a facilitator of learning, as a counselor in school, professional, and in career orientation; as a class manager, as a coordinator of the teaching staff, in general, of the teachers involved in STEM education / training, in particular; d) partnerships with the educational community local, supported both contractually and consensually; e) differentiated non-formal curriculum (microgroup and individual).[9]

STEM education is an educational model for learning the exact sciences: mathematics, physics, chemistry that requires theoretical interdisciplinarity and relevant practical applications, direct examples from nature or real life. Although the United States has historically been a leader in these fields, fewer students have recently focused on these topics. According to the US Department of Education, only 16% of high school students are interested in a STEM career and have proven their math skills. Currently, almost 28% of high school students say they are interested in a field related to STEM, says a department website, but 57% of these students will lose interest until graduating from high school.[10]

Values, actions and educational activities specific to STEM education

The acronym STEM (Science, Technology, Engineering, Math) stands for an educational model of learning the exact sciences: mathematics, physics, chemistry in an integrated way with applications and direct examples from nature or real life. Like any other education system, STEM education is based on several clear principles that must be applied to achieve the goals of

[9] Lixandru F.I. et al. Educaţia STEM – o necesitate în strânsă conexiune cu realitatea (II). In: Tribuna Învăţământului, no. 1443 (3323) in 4.06-10.06.2018

[10]https://maraandtom.ro/educatia-stem-ce-este-principii-jucarii-stem/

education in the training of future adults. The principles of STEM education aim at:

a. Quality and rigour

- ✓ aligns and integrates the content of curricula, including the Early Learning Framework, the curricular areas of science, technology (design and digital technologies and technologies) and mathematics and accredited secondary education;
- ✓ completes the teaching and explicit evaluation of the disciplinary content and key ideas in the component disciplines of the curriculum. Design and technologies include engineering principles and systems.

b. Relevance and authenticity

- ✓ uses authentic real-world challenges and contexts that require the integration of disciplinary approaches
- ✓ provides applied learning contexts that are relevant to the learner
- ✓ creates customization opportunities

c. Capacity and availability

- ✓ uses student-centered pedagogical approaches that allow self-direction, collaboration, problem solving and project management
- ✓ develops general skills and, in particular, critical and creative thinking, literacy and calculation in applied and contextualized learning settings
- ✓ stimulates innovation by creating, designing and producing solutions to real world problems.

d. Inclusive and affordable

- ✓ provides access and challenges for all children
- ✓ uses a differentiated approach to planning, teaching and evaluation
- ✓ creates resilience and a growing mindset for all children when faced with challenges and uncertainty.[11]

For the development of STEM skills, the tasks and learning situations developed by teachers will highlight interest and curiosity (asking relevant questions), inventiveness and creative imagination (create new solutions, formulate plans, conduct research), intellectual behavior and pragmatism (capitalize on previous experiences and apply what they discovered in the real world). Non-formal and formal activities, both supported by the STEM education approach, not only expose children to unique, interesting/fascinating and effective learning experiences, but also help them to support an innovative

[11] https://maraandtom.ro/educatia-stem-ce-este-principii-jucarii-stem/

approach that they can use/multiply in adulthood.[12] Thus, STEM-type activities will not only be interesting, in the sense that they encourage and emphasize exploration, experimentation, they satisfy their need for knowledge, curiosity, but also relaxing, discreet. By encouraging constructive dialogue, the active-participatory attitude is maintained, which leads to the creation of an environment in which children learn to collaborate, to listen actively and to implement the ideas of others; thus, the energy needed to solve problems can be provided. Metacognition training can improve the attitude towards school tasks, towards the school organization and positively influences the students in terms of their own learning, corroborated with the increase of the potential to work in a team, which supports not only the interaction, mutual knowledge but also the experiences of cultural pluralism.[13]

At the same time, active rest is also worth mentioning, in the sense that STEM activities are very hands-on - they require the physical involvement of the participants and multisensory experiences that help children fall in love with what they do. It should be noted in this context that STEM education capitalizes not only on the potential of each student, but also on their own learning style through the multiple approaches that are put into play.

One of the most valuable components of STEM education is encouraging children to come up with new solutions. The need for diversity, customization of solutions is emphasized, which implies the identification of several solutions derived from opinions, options that are expressed, developed and tested. Throughout the process, children are actively involved and they are constantly learning from each other. STEM education emphasizes the aspects of effectiveness, in the sense that emphasizes the educational process (content, teaching methodology) more than efficiency (results quantified in grades, awards). Of course, the purpose of educational action is to learn with a focus on finding the best solutions to the problems identified, but STEM is more than the ultimate goal.

STEM education weighs more and more in the society, particularly since society is more and more governed by the new technologies. These types of skills prepare people to access some of the most important future professions, including a large number of experiences and skills in various fields.[14] Due to such training, students are allowed to have the ability to

[12]Manea, Adriana Denisa. " Lifelong learning programs-an effective means of supporting continuing education", Procedia -Social and Behavioral Sciences, 142/2014, pp. 454-458, doi: 10.1016/j.sbspro.2014.07.648;

[13] Stan C., Manea A.D. "The Dimensions of Intercultural Education", Astra Salvensis, 12/2018, pp.291-297

[14] Manea, Adriana Denisa, "Coordinates of Lifelong Education", Astra Salvensis. 5/2015, pp.168-171; Manea, Adriana Denisa . "Features of educational activities in the contemporary society". Astra Salvensis, VI, 12/2018, pp. 255-260

solve very specific problems. The educational system has had to adapt to the new social trends and needs.[15]
The benefits of STEM education are remarkable both individually and in groups / collectively. Thus, teh creative potential is stimulated by the fact that STEM education requires unique ideas and at the same time complex problem-solving processes with an interdisciplinary approach. This skill is developed with inspiration from other teammates who are encouraged by the trainer to explore new things, use their imagination and build their invention. Another benefit is the development of teamwork skills. The ability to collaborate is the ability to work together for common goals and in this way communication and leadership skills can be developed. In the realm of intellectual skills we find the direct benefits of STEM education in developing communication skills (learning to give and receive feedback effectively), improving cognitive and critical thinking skills, learning how to break down a problem into smaller parts and solve step by step, learn the basics of coding and engineering), strengthening media literacy (STEM students learn through research and investigation; the survey requires them to engage in active learning by generating questions and looking for answers on a daily basis). Other important benefits are found in the attitudinal-behavioral sphere, materialized in the spirit of initiative and curiosity. STEM education helps raise children who are curious, confident and more challenging. They can think of their own projects to solve problems. In the social sphere, the benefits are found in exploring young STEM careers (STEM education prepares children for the future to include the basis of innovation, science and technology) and the development of socio-emotional skills (social-emotional skills facilitate positive interaction, well-being , ensures success in life - professionally, socially and personally).

Conclusions

In addition to emotional intelligence, STEM education is an important asset for children, which requires its integration into their early development, as the challenges of STEM education include the idea of teamwork (working / learning in cooperation and collaboration), dialogue through development and the addressability of relevant questions, the search / selection of correct / important information and their contextualization in order to discover the best solutions.

In addition to the benefits mentioned above, specific benefits of STEM education include: promoting proactive learning, integrating ICT into school and social learning, creative problem solving, developing fine motor

[15]STEM: educația prezentului și viitorului https://www.hwlibre.com/ro/stem/

skills, entrepreneurial skills, ease of learning and using concepts. practices, increasing self-esteem and managing emotions. In the long run, it is considered that a good personal development will allow children benefiting from STEM education to carry out effective activities in socio-professional environments. An integrative culture aimed at STEM education involves getting rid of the archaic system of passive, memorial and theory-based learning and adopting a leading attitude of educational action, with a learning based strongly on experiential-exploratory, practical-applied principles. The basic principle of learning is to learn by doing. Therefore, the student will learn to solve his own problems on his own, to develop, to design, to experiment and to test the results in order to draw his own conclusions. Contemporary learning is associated with desirable change. The learning process produced in formal, informal and non-formal environments is dependent on both the individual and the society, respectively the environment in which it operates.[16] Thus, the self-taught, responsible approach supports self-learning and learning performance.

The world and our image of it are constantly changing, according to our perceptions, reflections, actions. Personal feelings and our imagination fully contribute to the way we represent and transform reality. Therefore, the capacity for cognitive restructuring, adaptability to the new, continuous and creative flexibility of contemporary man (child and adult alike) are increasingly required.[17] Moreover, imaginary experimentation is able to allow the accumulated knowledge to become emotionally significant, and the parameters responsible for the formation of moral attitudes to become operational. Thus, the opposition / discrepancy between knowledge and affectivity could be solved, the affective resonance being able to give meaning to the knowledge, being at the same time generating generative attitudes towards the learning /development process in general.

Awareness and acceptance of the role of the school in the formation and development of personality, in professional and multicultural training, in career guidance and counseling allows us to consider the school as a launching platform for achieving personal ideals.

[16] Adriana Denisa Manea, "Features of Educational Activities in the Contemporary Society", Astra Salvensis, VI, 12/2018, pp. 255-260

[17] Adriana Denisa Manea, "School- the axis of knowledge", Globalization and National Identity. Studies on the Strategies of Intercultural Dialogue / Ed.: Iulian Boldea, Tîrgu-Mureș: Arhipelag XXI, 2016, pp. 269-275