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CONCEPT ON STEM EDUCATION IN ACCORDANCE WITH BULGARIAN CURRICULUM CONTENT OF SECONDARY SCHOOL

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Abstract. Main concept in STEM education is implementing of synergetic potential of connections across different disciplines. It must be based on their results and broaden their comprehension by interpreting in applied context to achieve new meanings. In the report is presented a concept for STEM education on the ground of Bulgarian curriculum for disciplines in secondary school. The concept is described as relationship: learning outcomes-content-sample tasks for implementation.

Keywords: STEM education; competency-based approach

Introduction

The modern educational paradigm is characterized by the search for a balance between personal and public interest in pedagogical interaction. On the one hand, individual characteristics and abilities are taken into account and developed, and on the other hand, the development of personality qualities that are socially useful and will allow successful socialization and integration in public relations is aimed at. In the conditions of increasing influence of technology on all social spheres, finding the place of man is becoming more and more difficult. Routine human practices are implemented more and more successfully by technology, and for man the only thing left is the process of creating a novelty, and one that will win in the competition with artificial intelligence. In the picture outlined in this way, the main ideas about education, on which the construction of international education policies and national education systems are based, naturally stand out - learning based on learner activity, integrative project-based tasks, authentic learning and assessment, development of teamwork skills and creative problem solving etc. In this educational context, the influence of the idea of the connection between science and technology, which is reflected in the concept of STEM education, is growing. When deriving the essential characteristics of STEM, a number of features of the modern educational paradigm are indicated such as: integrative curriculum and multidisciplinary approach (Aguilera, Ortiz-Revilla 2021; Kakarndee et al. 2018; Öztürk, Seçken 2017; Sanders 2009;

Pinasa 2019), situational and authentic learning (Altan, Tan 2020; Bybee 2013; Kakarndee et al. 2018; Öztürk, Seçken 2017), critical thinking, inquiry and creativity (Aguilera, Ortiz-Revilla 2021; Bybee 2013; Ozkan, Topsakal 2019; Wannapiroon, Petsangsri 2020). A number of studies show that STEM develops creativity regardless of whether the program specifically includes the arts (STEAM) or not. (Aguilera, Ortiz-Revilla 2021). Interdisciplinarity as an essential characteristic leads to the idea of connecting not only these four or five disciplines, but also beyond them – with reading and writing (STREAM) or with social sciences (Park, Cho 2022), which finds its explanation in the metacognitive skills that are primarily developed through STEM education. From a neuro-physiological point of view, tasks that require complex (from the perspective of the performer), non-standard decisions activate multimodal associative fields in the cerebral cortex. Three main areas in the cerebral cortex are associated with multimodal associative activity:

1. Limbic association area – located in the anterior ventral part of the temporal lobe. Connects emotions with sensory information. Important for learning and memory.

2. Posterior associative zone – located at the border area of the occipital, parietal and temporal lobes of the brain. It links information from the primary sensory and monomodal associative areas. Connects perceptual information and speech. In this area is Wernicke's field, associated with understanding the meaning of written and spoken speech.

3. Front associative area - connects the information from other associative areas. It is important for memory, planning, conceptual thinking, it is activated during creative activity. Here is the other important area related to speech – Broca's area, which is responsible for the production of speech (Gazzaniga, Ivry & Mangun 2019).

In general, the function of the three multimodal associative fields is tied to the establishment of connections and relations between the received information through all channels. On the basis of the sensations and the memory of the experience, a behavioural response related to movements, speech, planning and triggering mechanisms of behavioural responses is developed. Obviously, the tasks that are related to the development of metacognitive skills in the context of STEM education should provoke activity in the highly integrative areas in the cortex of the terminal brain and foresee the participation of speech – written and spoken, establishing meaning by connecting information from different perspectives. The very process of meaning-making implies the discovery of connections in different planes:

(i) ontological (semantic) – establishing a relationship along the lines of Frege's triangle (idea – sign – meaning);

(ii) epistemological – established on the link between idea – meaning – methodology;

(iii) axeological – connection between idea – values – methodology

(iv) praxeological (technological) – idea – technologies – methodology (Figure 1).

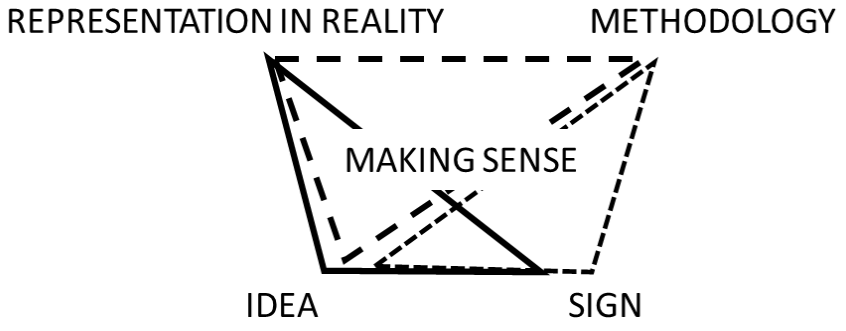

Figure 1. Main interactions and planes in process of making sense (Raycheva 2019)

The making sense process can take place repeatedly and at different levels of acquiring experience (knowledge, skills, relations) – primary (during the initial formation of concepts, skills and relations) or secondary (when discovering new connections and relations, upgrading the content of concepts etc.). The development of metacognitive skills presupposes the presence of a "primary substrate", an existing cognitive resource through which and in the context of which the process of developing these skills can unfold. In other words, problem-based, project-based, creative and critical thinking presupposes a foundation, an existing experience of the facts and concepts involved in the thought process.

These grounds, placed in the conditions of application of STEM education in a built subject-centric educational system, such as the Bulgarian one, raises the question of finding a connection between the subjects and in a context that is relevant for the students' experience. The process of integration should support the assimilation and achievement of permanence of the knowledge that is the object of study in this period. In any case, finding common themes for STEM is one of the main challenges (Bybee 2013; El-Deghaidy, Mansour 2015). The challenge is even greater to find meaningfully significant, from the point of view of the current development of the student's cognitive experience, thematic areas in the limited territory of already built concepts of educational content based on the internal logic of individual educational subjects.

Walker et al. 2018 proposed two frameworks with tenets and indicators of „effective integrated STEM lessons and effective engineering education". In designing STEM curricula and instruction „eight tenets of quality of STEM integration environments are proposed: (1) engage with a personally meaningful and motivating

context; (2) participate in an engineering design task with a compelling purpose that involves problem-solving skills and ties to context; (3) learn from failure and have the opportunity to redesign; (4) learn appropriate standards-based mathematics and/or science content; (5) explore content with student-centered, research-based pedagogies; (6) participate in teamwork and communication skills; (7) use evidence-based reasoning to integrate engineering with mathematics and/or science; and (8) engage in engineering design“ (Walker et al. 2018).

Methods

Based on a content analysis of the curriculum for the subjects of biology, chemistry, physics, mathematics, art, music and technology and entrepreneurship for low secondary and secondary school, topics suitable for STEM education for secondary school were identified. The content was constructed based on the following criteria:

(1) Be consistent with content topics from at least two different subjects at secondary level.

(2) To make a connection with available knowledge and skills from previous years where possible.

(3) To have activities that can be applied in different grades and in the context of learning in a specific subject.

(4) The activities should be related to achieving the learning outcomes defined in one subject and at the same time support learning in one or more other subjects to make sense of the studied concepts in real life.

The main skills in the proposed concept, through which the goals of STEM education are achieved, suggest that the student should:

(1) Applies dependencies of mathematics and science in reasoning a decision.

(2) Develops cause-and-effect relationships in the relation science – technologies.

(3) Analyzes information in texts, diagrams and images with a specific purpose.

(4) Presents ideas through creativity.

Results and discussion

Based on the analysis of the curricula, learning objectives were derived for the subjects, which can be integrated through relevant topics for STEM education (Table 1). On their basis, examples of activities are proposed.

Table 1. Subjects and learning outcomes as a base to define topics for STEM

Subject and class	**Topics and learning outcomes1**
Human and Nature 6th grade	1. Motion and forces Characterizes force as a physical quantity with magnitude, direction and application point. 2.1. Irritability and movement Illustrates with examples movements in plants and animals.
Physics 8th grade	1.3. Balance of bodies Describes the types of equilibrium of bodies (stable and unstable) depending on the position of the center of gravity.
Chemistry 8th grade	2.1. Metals in IIA Group Explains the practical application of metals with their physical and chemical properties.
Biology 7th grade	3. Vertebrates Compares fishes, amphibians, reptiles, birds and mammals by essential features. Traces in evolutionary order the main groups of vertebrates.
Biology 8th grade	3.1. Human skeleton and skeletal muscles Lists, describes and designates (on a diagram, image, model) a device and functions of the organs of the musculoskeletal system.
Art 8th grade	Technologies in Fine Arts – painting, graphics, sculpture Understands the features of building sculptural form.
Sample topic for STEM: FORCES – BALANCE – MOVEMENT	

Following the illustrated way to define topics for STEM, for the 9th and 10th grade, respectively, topics such as Energy and Evolution, etc. can be brought up.

The activities for the relevant topics must be consistent with the learning outcomes and allow flexibility in the application, depending on the possibilities of the relevant educational situation. Below are four sample activities on Forces – Balance – Movement topic:

Activity 1

The diagram shows examples of how the limbs are attached to the body in different vertebrates. In each of the examples, note the center of gravity of the body. Compare the plane on which the center of gravity is located with the plane of attachment of the limbs.

Determine in which of the cases 1, 2 and 3 the body will be in contact with the surface on which it moves and why? (Figure 2)

In which of the cases will the animal be able to develop the highest speed of movement on land and why?

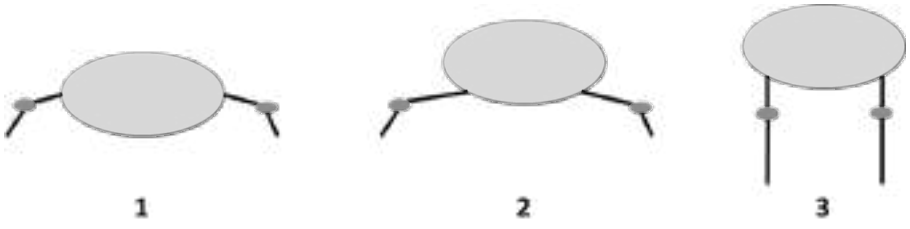

Figure 2. Examples of how the limbs are attached to the body in different vertebrates

Activity 2

Analyze the walking pattern of animals with three pairs (six) legs (class Insecta) and with two pairs (four) legs (classes Amphibians, Reptiles and Mammals), given on picture below, and make a description of insect locomotion. Determine how many fulcrums there are on each side in both cases and why? (Figure 3).

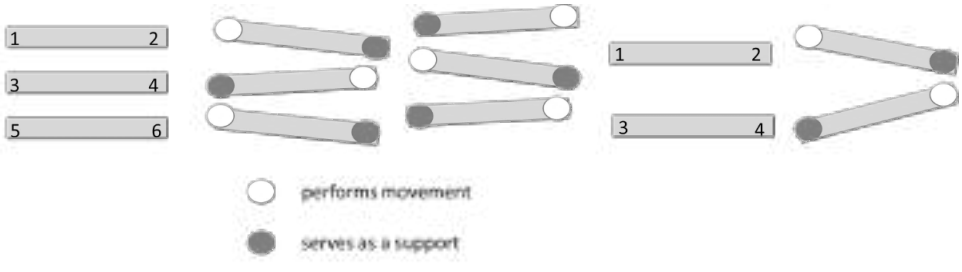

Figure 3. Walking patterns of animals with six and with four legs

Build a similar pattern of spider walking (four pairs, eight legs). How does a spider keep its balance? Justify using a diagram. Compose text to describe the movement of the spider and animate the movement using a suitable computer program.

Activity 3

Calcium ions are important for realizing the work of the muscles. They "unlock" the interaction between the two main types of filaments that slide against each other and so the muscles generate force. Magnesium acts as a calcium antagonist and is recommended to prevent muscle cramps.

Explain, by analogy with antagonist muscles, what it means in the text that

"magnesium is a calcium antagonist" and why magnesium helps fight uncontrolled muscle contractions. Guess why exactly magnesium can "block" the function of calcium ions.

Activity 4

For each of the given examples of plastic art (different photos of scuptures, presented balance), suggest a word or sentence that you think expresses the idea of the sculpture. How could you express this idea by creation and art?

The given activities are related to the expected results from table 1, for example, activity 1 implies the determination of the centre of gravity and the analysis of the point of application and the interaction of forces during the movement of bodies (organisms). At the same time, a connection is made with what has been learned about the adaptations of animals for life on land, including the development of limbs and modes of locomotion. The second activity also suggests a connection with what was studied in previous years about the number of limbs in different animals and ways of moving on land. What is learned is applied in the analysis of fulcrums for maintaining balance during movement. The task also implies a connection with technology. Activity 3 illustrates the connection between biology and chemistry and can be applied to the topic II A group comparing calcium and magnesium, as well as in biology to the topic of muscles and muscle contraction. Activity 4 shows the connection of knowledge from different fields of science with ideas and the source of inspiration for creative expression.

The given activities do not exhaust the possibilities of learning on the proposed topic, but only illustrate the idea.

Conclusion

Creating a STEM environment isn't about classrooms and equipment. First of all, this presupposes the existence of a content concept and resources for implementation in the pedagogical interaction (tools and methodical guides) and in accordance with the existing educational documentation, with the developed content concepts for the educational subjects. Otherwise, isolated implementation through chaotic, unfounded, from the point of view of the objectives in the curricula, topics creates more chaos, disconnection and confusion in the minds of the students. This is in complete contradiction with the ideas of STEM education for making sense in relation sciences – technologies – real life.

NOTES

1. CURRICULA BY GRADES FOR BULGARIAN SCHOOLS. Available from: https://web.mon.bg/bg/

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