Chapter

STEAME Model in Action: Challenges and Solutions in Mastering the Digital Culture

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Abstract

Due to the digital transformation of everyday practice the process of education has become more complicated than ever before. The role of teachers is more complex as they are not the only source of information and knowledge for their students anymore. Formally or informally, they need to help students develop new competencies and prepare them for the unknown future in the fast-growing and changing labor market. Essential part of these new competencies lies in the interconnected fields of Science, Technology, Engineering and Mathematics. In order for students to obtain them a variety of learning approaches have to be applied in an interdisciplinary educational environment and digital culture. The new generations of digital natives grow up with a set of skills about engaging in the digital world as a basic knowledge. Furthermore, to provide students with more holistic understanding the concepts of Arts are integrated with STEM to become STEAM education. This chapter presents extended education model taking STEM and STEAM to the next level and bringing the Entrepreneurship discipline to create an integrated STEAME curriculum. This chapter presents an integrated STEAME curriculum model, methodology for its implementation and STEAME classroom and environment design as a new education approach to tackle the challenges of the development of skills for the 21st century.

Keywords: Digital Culture, Education, Challenges and STEAM, Education for sustainable development (ESD), digital natives

1. Introduction

Nowadays the world is changing faster than ever affecting all aspects of our lives including the way students learn and teachers have to respond quickly to their learning needs. Global economy and job market have also imposed challenges with a higher demand of new qualifications and skills. In order to be competitive, the workforce has to adapt with the same speed and according to the expectations and needs of the contemporary employers. This adaptation is not possible without the crucial role of education as its main objective is to transfer the knowledge to the next generations as Montessori said that the education is natural process for humans achieved by meeting the complex challenges in the real world [1].

And from Seymour Papert's constructionism point of view "*students construct mental models to understand the world around them*" [2]. The information technologies support additional possibilities - created public entity can be shared. This leads to change towards a digital culture for students as digital natives and digital immigrants - most of the teachers [3]. The synergy of disciplines in the classroom will give students a broader vision of the world as it is in its integrity. In the past 20 years such pedagogical approach has been developed to create STEM (Science, Technology, Engineering, Mathematics) education. It is further upgraded to include arts and become STEAM and now entrepreneurship is integrated as well to become STEAME.

The interdisciplinary STEAME (Science, Technology, Engineering, Arts, Mathematics, and Entrepreneurship) education focuses on developing such essential skills as creativity, problem-solving, engineering literacy and entrepreneurial spirit. STEAME as a newly developed approach for integration of these disciplines conveys very good results and positive feedback so far. This is directly related to the fact that in the past few years pursuing STEM careers has decreased and the education system needs to make extra efforts to encourage students to work in these fields. This would be possible and much easier by applying innovative methods, approaches, tools and technologies to the education process. Furthermore, teachers who are digital immigrants need to be supported in this endeavor by development of new skills and methodologies like innovative thinking, design thinking, lean and agile methodologies, new role of a coach and mentor. Teachers have to prepare students for real life full with technologies and necessity of faster adaptation and flexibility.

What kind of new knowledge and skills students should develop at school level? Are these sufficient and well accepted by employers? How are students motivated to learn and develop their abilities?

These and many other questions are asked by teachers. The complexity of our dynamic world puts the focus on the development of interdisciplinary knowledge, abilities and skills. STEM (Science, Technology, Engineering and Mathematics) upgraded to STEAM (Science, Technology, Engineering, Arts and Mathematics) and the newest STEAME (Science, Technology, Engineering, Arts, Mathematics and Entrepreneurship) are empower schools to improve science and technology development.

This chapter presents a model for implementation of STEAME (Science, Technology, Engineering, Arts, Mathematics and Entrepreneurship) education and provides an overview of how to be designed and integrated at school level.

2. Bulgarian roots

The interdisciplinary approach has deep roots in Bulgarian education. Scientific research on the effective utilization of computers and information technologies in the middle school has been done in Bulgaria as early as the end of 70-ies [4]. The Research Group in Education (RGE) at the Bulgarian Academy of Science and Ministry of Education developed a curriculum in which the cross-disciplinary study of language and mathematics (actually one of their text titles: Language and Mathematics) and Logo-based computer are in a synergy. The learning activities played prominent roles for students' motivation and their understanding of the complexity and dynamics of the world around them.

The research group had the task to develop and experiment with new curriculum based on the following principles:

- integration of academic disciplines;
- learning through action and discovery.

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The developed curriculum was implemented in 29 schools from different parts of Bulgaria in the period from 1979 to 1991. It was an experiment conducted by scientists across all fields. Prominent poets, writers, artists, cartoonists, musicians took part in the development of the textbooks (**Figure 1**). The leader of the authors' team was Blagovest Sendov. It is renowned for its intriguing texts (Valeri Petrov and Marko Ganchev), artistic design of Donyo Donev, the ideas for language integration with mathematics (Rosalina Novachkova, Blagovest Sendov and Boyan Penkov).

During the first four years, computer science was an element of encyclopedic training. Some basic computer concepts (algorithm, coding, decoding, table, graph, procedure, data) were applied in various learning activities.

The textbooks and classes developed on the basis of Logo stimulated and supported the research style of learning in all classes. The specifics of the traditional school with fixed classes and relatively large groups of students were taken into account. This required a certain modification of the flexible style of work experimented in the USA and England by teams of experts in psychology, computer science, artificial intelligence, with groups of children in the framework of ambitious projects for schools of the future.

The experiment finished thirty years ago. However, the society was not ready for that. This was the start of applying new approaches and use of technology to develop the necessary digital culture.

During periods of dynamic changes and advances of technology teachers and students have access to them. The new information technologies (IT) look attractive for the younger (digital natives) generations and intimidating for older generations (digital immigrants). The teachers are afraid that IT prevents them from being professional in their fields when they are not fluent in technologies [5]. Under this pressure somehow teachers forget to transfer the most important message to the students – love for studying. Nevertheless, the educational big challenges are *where*, *which*, *how* and *why* to use IT. The most important in the new pedagogical approach supported by technologies is that it has to be active and student-centered. The theoretical knowledge of active learning is not enough to be applied easily and to present adequately the teacher's expertise.

This experiment was a base for further scientific research on the effective utilization of computers and information technologies in the middle school has been done in RGE [6, 7]. This research is intensified in the context of several European projects [8] and it is still an inspiration for ongoing research tailored to the new

Figure 1.
Textbooks: Logo - 1st grade, 3th iand 4th.

generations. One of the main directions of the educational design is inquiry-based learning for interdisciplinary education [9–18].

The improvement of learning methodologies is a long process. The results are visible at least 10 years after the application. Most of the current teachers are focused on their topic(s) and the interdisciplinary approach integrated with new technologies for teaching and learning is a challenge for them.

3. STEAME curriculum

The technology-driven economy and skilled workforce in STEM (Science, Technology, Engineering and Mathematics) fields are considered the driving forces for innovation and growth. However, a number of European studies register a declining interest in students' interest and enthusiasm in STEM education. Thus, motivating secondary school students towards STEM careers is becoming a critical task. However, in a traditional school curriculum all or most of subjects constituting STEAM are taught separately. There needs to be curriculum adaptation to adjust the current one to the changing and emerging needs of all learners. Curricula are changed according to the new requirements and expectations, policies, priorities, circumstances. It has to reflect the different abilities of students and their strengths in different areas [19, 20].

School curricula must favor applied knowledge, inquiry-based teaching and invention: students' individual strengths emerge as they are confronted with challenges. Students acquire independent thought, learn to make decisions and act on them. At higher levels the overall educational programs giving content, mindsets, competencies, and skills works together with other special programs like internships and intensives. Educational goals must be centred around experience-based knowledge to develop critical reflection and commitment to action. In advanced courses students work independently and are encouraged to offer thoughtful responses to given questions and to think more abstractly. Through work-based experiences in STEAM subjects and Career Development programs focused on entrepreneurship, students develop an aptitude for real-world leadership and problem solving focusing on teamwork, communication and interpersonal skills.

4. Methodology

4.1 STE(A)M(E) – why?

Twenty years ago, the term STEM was introduced by scientific administrators at the U.S. National Science Foundation (NSF) as curriculum that is centred on education in the disciplines of science, technology, engineering, and mathematics [21]. STEAM variations are STEAM (A for Arts) and STEAME (E for Entrepreneurship).

STEM is a curriculum-based approach integrating four disciplines: science, technology, engineering and mathematics. This model of teaching and learning allows better understanding of these subjects in their mutual correlation and application in the real world. Science includes physics, biology, chemistry. The paradigm of synergy among them is based on the real-world examples and challenges [21, 22].

The integration of arts into this approach leads to the existence of STEAM model. This complimentary subject provides students with such skills as creativity, artistic abilities and knowledge about the world of arts. It allows teachers to better prepare them and to nurture artistic development. STEAM education leads to better preparation of 21st century innovators, leaders, educators and learners because to follow STEAM approach means to create, to take risks, to meet the problems and to find solutions [23].

The newest educational approach is STEAME [24] where entrepreneurship presents the last "E". These approach guides and builds one new layer of understanding of the real world - entrepreneurial mindset together with research, creativity, logical and critical thinking.

STEAME is introduced as results of the Erasmus+ KA2 project STEAME: Guidelines for Developing and Implementing STEAME Schools, project No. 2019-1-CY01-KA201-058240. This research presents the STEAME methodology as an upgrade of RGE's approach.

STEAME is challenging for teachers as any new cross-disciplinary educational approach and methodology. From one side they have to improve their ability to work in synergy and to cover a broad range of disciplines and teaching styles. On the other hand, they have to motivate students in these areas which are not that attractive and complex to learn. According to John Dewey education is *not a preparation for life; it is life itself*. Teachers should prepare students to realize the integrity and interconnectivity of the world and give them the opportunity to dive deeper into technical/scientific and artistic/humanistic fields to develop their real potential.

How to motivate and teach/train digital natives for the diversity today and the unclear future with disappearing and emerging professions? The answer could be STE(A)M(E)!

STEM - > STEAM - > STEAME education are not in opposition, each one enriches and expands (**Figure 2**) the scope of the previous one [25]. They:

- enrich school philosophy for curriculum which engages teachers and students;
- bring education to meet the needs of the dynamic 21st century in an integrated and holistic way
- develop a creative collaborative space for students and teachers in an integrated curriculum;
- can be inspired by real projects implemented in the learning programs;
- engage students in considering synergy of five sides of knowledge: culture, relations, criticism, vision and ethics, and its action which is transformative learning.

Seymour Papert says: *You Can't Think About Thinking Without Thinking About Thinking About Something*. In STEAME education creativity and problem-solving

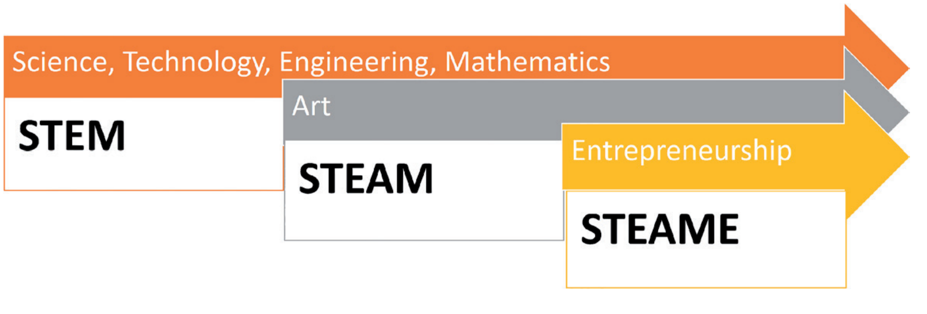

Figure 2.
STEM - > STEAM - > STEAME.

skills are on focus. Design and design thinking develop creativity and innovation, and have become increasingly important in the development and implementation of the integrated STEAME education. Design thinking is a problem-solving iterative approach traditionally applied by designers. It is now applied in business, education, and other fields to tackle problems and challenges following human-centered approach of six-step iterative process: Empathise, Define, Ideate, Prototype, and Test can be applied for science, technology, engineering, mathematics, arts and entrepreneurship [26]. Design of STEAME curriculum starts with empathy of digital natives. The learners are in the center of the training. Their understanding is crucial for effective learning. The digital immigrants have to be aware for their specifics. When creating such curriculum the following objectives are set:

- to connect concepts, ideas and different perspectives to provide new and innovative valuable propositions,

- to test them and re-elaborate with experience.

- to incorporate elements from other creative and design disciplines.

To facilitate and enhance the successful implementation of the model, learning units are designed and developed according to a number of learning cycles that, following a sequence of stages, promote the development of this independent, meaningful learning. Inspired by the model of Kolb [27] and St Ignatius' teachings [28] five stages are proposed for the development of a learning cycle:

4.1.1 Experiential context

"From known to unknown". It is first stage which gives students an introduction to the topic. The aim is to motivate students through their own experience and context so that they can have an initial general overview on the subject and the context in which it is especially relevant, or where the contents to work on can be applied.

4.1.2 Reflective observation

The aim of this stage is to encourage students to ask questions, to question themselves, as there cannot be significant learning if one does not ask oneself or questions about it. It can be a question, a number of questions, a conflict, or a gap between what I know and what I need to know or do; all that drives students into action and hence, to the construction and reconstruction of knowledge.

4.1.3 Conceptualization

The aim of this stage is to bring students closer to the theoretical approaches that have been developed in a specific scientific or technical area: the answers given by authors and schools to key issues in each discipline. Conceptual learning is based on the acquisition of knowledge, scientific terminology, facts and data, methods and strategies, principles and theories that make up the scientific and technical knowledge of each discipline. As the aim of the course is to move knowledge into action, it should be noted that Design Thinking is a new discipline in the academic world. It is a scientific approach that is closer to practice and used by designers as a problem-solving method. So, there are many real examples that can illustrate this phase.

4.1.4 Active experimentation

In this fourth learning stage, we consider how students can apply the contents they have just worked on. It refers to the theoretical/practical relationship and includes any activity (exercises, internships, projects, research work, designs or any other active proposal to be carried out by students on a specific subject, year or degree) that promotes the development of students' competences concerning the application of concepts, theories or models in order to strengthen them, use them for problem solving or to design or implement a model or strategy.

4.1.5 Assessment

We cannot complete a learning cycle without asking ourselves what we have done and what we have achieved. This is a final point to a learning cycle and it can be the beginning of a new one to refine all the concepts and skills that have not been sufficiently achieved in the previous one. Therefore, it helps go deeper into the subject in an iterative way.

This learning approach allows the training to be: Interactive: among participants, and among them and the users/customers, the teachers, tutors and business people that can take part in the training (in the Entrepreneurship discipline in STEAME); Participatory: making the team central for the learning process; Practical: learning by applying the skills and concepts gained in class in real life; Elicitive: learning from the experience of the participants.

4.2 Core challenges

Change and adaptation of methodologies, models and approaches require time and preparation including setting expectations, overcoming negative perceptions and attitudes, resistance to change. Myths are born, too. For example, in the early years of IT implementation [5] some teachers thought IT prevents their professionalism; the good teacher should know everything, etc. Nowadays students know more than their teachers. In the information age student behavior and knowledge are accumulated from diverse sources and means of communication. New myths are born such as finding the recipe for the successful and intriguing teaching.

Similar myths can appear in the implementation process of STE(A)M(E) education. There are curriculum development difficulties, lack of teaching resources and leaving the comfort zone when implementing the new process.

The core challenges in STEAME implementation are (**Figure 3**):

- Environment (physical and learning materials)
- Research and development capabilities
- Team capability and integration
- Digital transformation mechanism [29].

Development of a **user-friendly environment** supports effective teaching and learning and assures sustainability of educational project. The learning environment for STEAM(E) education can be as important to student success as quality instruction and course curricula. And in today's world, that means outfitting students and teachers with the right set of resources.

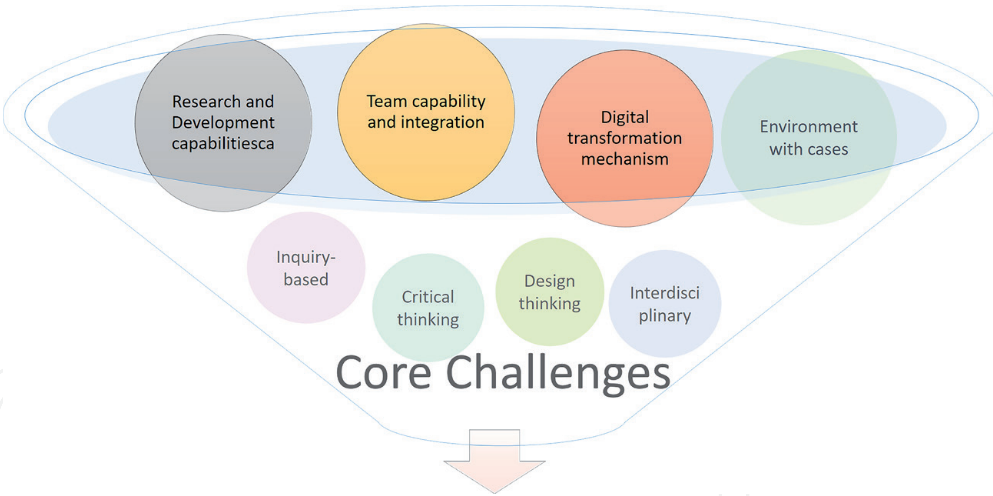

Figure 3.
Core challenges.

The STEAME program should facilitate design, not the other way around. The physical space can align with the principles of student agency, and teacher's flexibility, and choice that are at the core of the new model. Once is determined how students and teachers will interact with STEAME Curricula and blended learning, then the space could be planed accordingly.

The classroom layout should be aligned with the outcomes, that schools' Principles and teachers aim to achieve, when going STEAME and blended oriented.

Improvement of research and development capabilities: the use of case studies and real examples as sources are important to motivate students and help them choose their future career development.

In parallel the team efficiency, dynamics and competences are **developed**: it is essential in order to improve teaching and research capabilities. The team composition and **rapport** are critical for the success and development of effective training. The essential part in the digital transformation involved in this process is the use of **new, fast and frequently changing** digital technology to solve problems. Focusing on the transformation of scientific research topics, the transformation of advanced technology that is "unreachable" into a cognitive curriculum will help participants understand the development trend in advance and clarify future goals.

Attention should be paid when **the independent curricula are developed in combination** with the traditional approaches and systems, the national legislation, the contextual circumstances, digital transformation and innovation level, and the advantages of the research and development. There are already various good practices developed by individual schools across Europe and within the framework of EU and other projects.

The present case study is based on experimentation run in Bulgarian private school – Private English Language school Prof. Ivan Apostolov, partner in the project Guidelines for Developing and Implementing STEAME Schools.

The school has undertaken a pilot STEAME project for the students in 10th grade. For the purposes of the experiment a sample inquiry-based learning and creativity plan (IBLCP) was created. It is based on the integrated teaching process conducted by teachers in profiling disciplines (Entrepreneurship and Economics) and subjects from scientific and technological fields. The main thesis of the experiment is to create a model for applying the paradigm of STEAME training in an innovative way, looking for application of the synergistic effect of the studied subject areas in natural and applied sciences to an entrepreneurial outcome.

The main goal of the STEAME project (2019–1-CY01-KA201–058240) and the experiment in the Bulgarian school is to create an innovative model for applying the STE(A)M(E) paradigm, i.e., synergy of the classical disciplines with entrepreneurial outcomes and support of digital technologies.

The **learning objectives** are the acquisition of set of cross-disciplinary knowledge, abilities and skills.

One of the key success factors in this process is the flexibility and application of such approaches as: inquiry-based learning, cross-disciplinary teaching, problem-based learning, project-based learning, case-based learning.

Teachers develop and apply the so called learning and creativity plans instead of the traditional plans. They are used as guidelines with main steps, organizational matters, y-based learning for generating a creative plan for STEAME training, is based on the study of cases for interdisciplinary scientific, social, project and business realizations, as in addition to gather and analyze the necessary information, in order for teachers and students to identify disciplinary and interdisciplinary links with studied, in previous periods or at present, subject areas. This approach allows to demonstrate exploration skills by teachers and students, both in the period of research and analysis of the cases studied, and in the process of implementation of STEAM project development and its orientation to entrepreneurial results.

The model requires **students to develop and improve**:

Analysis of case studies and solutions. Inquiry-based approach is well known and applied by the teachers. Students also have experience in case-based learning and.

The model requires **teachers to master** the adaptation of the Interdisciplinary training and curricula; application of Inquiry-; Problem- and Project-based training approaches as well as the Case study description, decomposition and analysis.

Cross-disciplinary STEAME methodology. Together with mathematics and physics, the students are introduced to engineering inventions; technological innovations; robotics; information and communication technologies. Fine, monumental and graphical arts are part of the process, too. The STEAME model integrates the following social and behavioral disciplines taught at school: Sociology (Social Anthropology), Economics, Entrepreneurship, Ethnography.

Soft skill such as personal skills (creativity, critical thinking, emotional intelligence, etc.); interpersonal skills (leadership, social awareness, teamwork, communication, presentation, etc.); time management and stress resistance.

The model was tested with five teachers of the respective disciplines and five teams of students in 10th grade [30]: Team 1 – Mathematics and Arts; Team 2 – Arts and Chemistry; Team 3 – Anatomy and Arts; Team 4 – Engineering/Technology and Physics; Team 5 – Entrepreneurship.

All student teams worked on topics defined as projects within the described fields of their teams. They developed final presentations of the main findings and conclusions form their research and experiments.

5. Design the STEAME school and classroom

5.1 Main principles and tools

If the School is going STEAME and blended oriented to promote student and teacher agency, then the classroom should be redesigned to give many options and locations to teach and learn. The classroom layout must facilitate the outcomes that are expected.

Few innovative approaches for new organizational structure and design are applied:

Blended training system, based on real good industry and business practices and principles as:

- the optimal and efficient Lean Toyota Production System, Japan [31],
- the flexible and optimized programming methodologies in IT- Agile [32]
- the innovative models of production, business and life behavior - Design thinking of IDEO [33]

Flipped classroom [34]- a type of blended learning where students are introduced to content at home and practice working through it at school. It is a common practice for new content introduction.

IT tools for education support – there are many tools for online learning and for organization of the learning process.

Case study sets as:

- Epic [34] case study & analysis for STEAME Inquiry based learning within the frames of the School's Curricula.
- Backlog [35] is created on the base of conducted inquires in IBLCP in the framework of STEAME thematic plan.

5.2 Design and development

What should the STEAME classroom look like – students in rows, teachers writing on chalkboards, textbooks and so on? Technology and modernity of our times will transform the school and the classroom. In STEAME classroom, students and teachers are empowered to apply blended personalized learning and teaching. Through STEAME didactic technologies, time, classroom space, and teachers themselves become more flexible and adaptable. Students set their own goals and monitor their own progress under the umbrella of data-driven, targeted instruction and coaching. It means that students and teachers must have access to a structure for achieving relative curricula independence.

The mission of STEAME schools is to oppose the challenges of next endeavors in students 'life. The fundamental characteristic of this approach is to help students to understand who they are, what their interest and values are, what are their abilities, skills and talents. Teachers in the classroom can guide and motivate students as needed. The STEAME learning and training space is a joint classroom and there are three designated spaces for students and teachers to work – STEAME space, Science space and Creative space.

Personalized technology-driven approach is new and STEAME schools' premises must be designed from the ground up with this paradigm in mind. What about the existing school campuses? They should be adapted in order to meet the STEAME model.

What does the STEAME classroom look like?

The answer of this question is developed under the Erasmus+ project STEAME (2019-1-CY01-KA201-058240) where the team of Private English language school Ivan Apostolov created a pilot design of STEAME classroom.

The STEAME learning and training space is a joint classroom infrastructure with three designated spaces for students and teachers to work – STEAME space, Science space and Creative space (**Figure 4**). The classrooms are separated for each grade level, and for STEAME activities and the Humanity sciences, as well, but they should be supplemented by two auxiliary classrooms.

First, it should be a large room, open space interior design, and flexible infrastructure, because each place has its own identity within the STEAME classroom for blended learning;

Second, the classroom should be very purposefully designed in order the layout to allow teachers and students to organize in-class activities exactly what it needs to be;

Third, the nomenclature of different spaces in the school, is important to be clearly specified, because the role of Project-based, Inquiry-based, and Discovery-based learning that are the three basic learning methodologies applied in STEAME schools is critically important to be allocated appropriately;

Forth, the classrooms are separated for each grade level, and for STEAME activities and the Humanity sciences, as well, but they should be supplemented by two auxiliary classrooms (for STEAME by a seminar room and for Humanity's by a Lab;

Fifth, the organization of the space in the STEAME school is determined by different learning environments, and each environment is defined by the furniture, the architecture or space, and the finishes, for example:

- Introspective space for personalized learning, individual research activities, assisted by online or offline content (texts, graphs, pictures, audio and video content) digitally delivered via Chromebooks;

- Exchange space for collaborative learning with peer delivered content;

- Direct instruction space for limited number of students (10 to 12) focused around a whiteboard, smartboard, flipchart, and/or projector for direct delivery of educational content by the instructor;

- Studying space which is soft seating informal environment where independent individual or group (in small groups) learning can take place;

- Feedback space for the teachers in the STEAME learning process.

Sixth, in the STEAME classroom must support critical thinking collaboration with technology-enabled, teacher's led instruction for each grade, as well as, to be

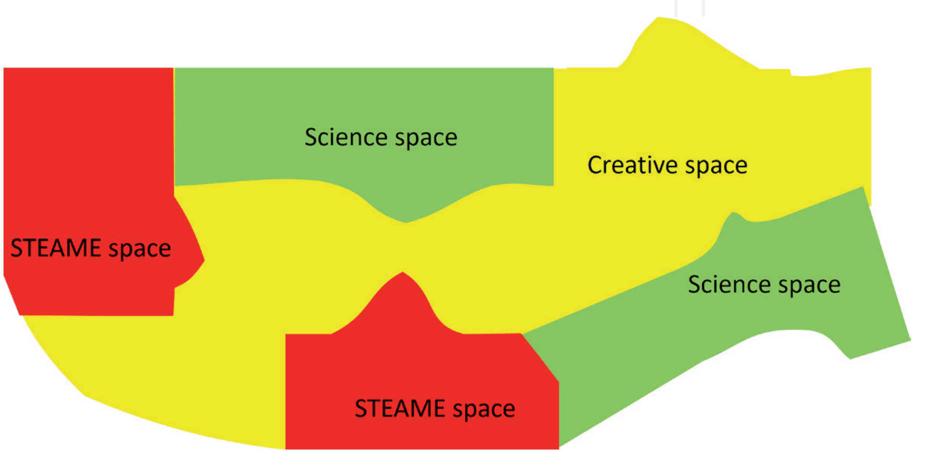

Figure 4.
STEAME classroom according the vision of Deyan Doykov, teacher at School Ivan Apostolov [30].

designed for structured group work within the project-based learning, in the same time a specific classroom space must be available for big ideas, discussions and connections;

Seventh, the classroom should be designed in such a way, to support independence end personal space for individual work;

Eight, the classroom space should support students' assessment and possibility for measurement of their personal and collective progress;

Ninth, the design of the classroom must support the STEAME teaching mode for providing life-changing opportunities and post-secondary success;

Tenth, STEAME classroom must support the roadmap for all other interdisciplinary educators.

The STEAME school model should ensure the interdisciplinary approach of its topics, incorporating a multifaceted exploration and study of a subject that ensures transferable knowledge and its applications. The synergy of disciplines with cross-thematic approach builds a more holistic understanding of the real world with real applications of abstract concepts. This motivates students to find solutions to real challenges.

6. Conclusion

The world is facing challenges in terms of meeting the changing social, economic and technological advances. The labor market is developing faster than ever with many new jobs emerging and some traditional ones – disappearing. These circumstances require new sets of skills and knowledge. Some of them are creativity, problem-solving, teamwork, leadership, digital literacy, social awareness, emotional intelligence, and entrepreneurial mindset. Educational systems have to be more flexible, creative and effective in order to meet the demand of the labour market of these new skills. The integration of Science, Technology, Engineering, Arts, Mathematics and Entrepreneurship into a new STEAME model and curriculum at school level provides a new paradigm and approach for preparation of students to empower them with skills and knowledge for the future.

It leverages on the STEM (Science, Technology, Engineering and Mathematics) and STEAM (Science, Technology, Engineering, Arts and Mathematics) education and incorporates Entrepreneurship as a subject area.

The integrated STEAME curriculum model is developed for the needs of the education of 21st century and based on the conducted experimentation and research proves to be successful.

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