Architectural and planning principles of STEAM-space organization

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Abstract. The article discusses the issue of organizing the educational space for the implementation of STEAM technology. The purpose of the article is to reveal the features of STEAM learning and to formulate the principles of organizing the learning space for this type of learning. On the topic of the research, a brief overview of the implemented architectural projects of educational spaces using STEAM technology was carried out. As a result, the authors identified architectural and planning features and principles of organizing spaces for STEAM training and created a model of an art and technology lyceum using the obtained principles for organizing a block of informatics and 3D modelling.

1. Introduction
STEM technology (science, technology, engineering, mathematics) is one of the most promising educational technologies, which confidently takes its place in the global educational trends. In 2015, a large-scale study of the European Schoolnet was carried out by an international organization consisting of the ministries of education of 31 European countries. [6] According to the results of the European Schoolnet study, 80% of countries noted STEM education as their priority and are developing several educational reforms that involve the use of STEM technologies.

STEM (science, technology, engineering, mathematics) approach is a wide range of actions, practices and techniques that are focused on the application of knowledge and skills from different scientific fields in one project. [4] For arousing of students' interest in technical subjects and give the finished product an aesthetic and philosophical component, it was decided to add an art component to STEM technology, resulting in STEAM technology.

For the successful implementation of this technique in educational practice, a particular educational space is required. This article analyzes the features of the implementation of STEAM technology and identifies the principles of organizing the learning space for STEAM technology. The authors have created a model of an art and technology lyceum using the principles obtained for organizing the block of informatics and 3D modelling.

2. Materials and Methods
The main theoretical research methods are the analysis and generalization of scientific literature and electronic publications on the topic, analysis and systematization of the essential characteristics of the space for organizing training in STEAM technology. For creating a model of the lyceum, the project method, the method of "getting used for the role" and the modelling method were applied.
3. Principles of organizing educational space for the implementation of STEAM technology

3.1. Necessary conditions and features of the organization of the STEAM learning space

The basis of STEAM training is formed by interdisciplinary projects; it is a kind of problematic situations that are set by the teacher. The goal of STEAM technology is to develop creative thinking, skills in using an engineering approach to solving real problems, understanding the importance of design, and understanding the role of technology in solving them. [1]

For being successful in implementing this educational technology, it is necessary to simulate an appropriate learning environment that is different from the standard classroom in the school. [3] At the stage of developing spaces that will correspond to the project-based and interdisciplinary nature of STEAM- learning, it is necessary to take into account many conditions and features of organizing the space for STEAM-learning:

1. The project activity is the main one, i.e. most of the classroom space should be dedicated to creativity and project development. [5] The geometry of the room can also be not standard rectangular, but square or hexagonal, which may allow for better positioning of furniture.

   It is worth considering that when organizing project activities, active training, and a constant change of activity is a need. With this form of training, traditional lectures are rarely used, preference is given to discussions and creative practices.

2. Availability and active use of technology. The educational space should be filled with the necessary presentation equipment that allows teachers and students presenting their ideas (mobile magnetic whiteboards, plasma panel, multiple displays and a projector). Students have quick access to laptops or tablets with the necessary software, microphones and headphones. Uninterrupted Wi-Fi and power supplies are of great importance, which students can use not only during but also after classes, in the course of independent work on a project.

3. Continuous learning, which involves working on a project not only during the lesson. After classes, students should be able to engage in discussion and revision of the project in special informal spaces – coworking spaces, laboratories and other types of activities. Access to such premises should always be open.

4. An interdisciplinary set of educational programs means a specialised curriculum and a convenient location of classrooms for related disciplines and joint projects. This circumstance is in line with the trend to use an integrated curriculum rather than teach related subjects in isolation.

3.2. The principles of organising the educational space for the implementation of STEAM technology

Today STEAM-training has established itself as a progressive educational technology. Over the past ten years, attractive educational spaces have appeared in the world that reflect not only the ideology of STEAM learning but also modern aesthetics and design. The following examples reveal the architectural and planning features and principles of organizing spaces for STEAM training.

ARC / Architectural Resources Cambridge, 2013, UK.

In the ARC project, the educational organisation needed to provide space for the implementation of an integrated curriculum. For this, the architects have completely united two different "wings" of the building – "Science" and "Mathematics". In the new project, science and math classrooms create a single space, excluding separate study laboratories and classrooms. Courses such as computer science, robotics, and high-level DNA research are also being incorporated into the new centre, which in turn will strengthen the technological and engineering components of the STEM curriculum. [2]

Laboratories, classrooms and ancillary facilities are designed to accommodate a variety of activities. Students and teachers of presentations, group discussions and projects, individual research work (Fig. 1), can use space for demonstration. The flexibility and mobility of the classroom allow varied the learning process, and the presence of transformable furniture allows changing the environment for individual or group exercises.
3.3. HMC Architects, Fremont Academy of Engineering and Design in Pomona, Calif., 2015, USA

At the Fremont Academy of Engineering and Design in Pomona, California, architects from HMC have solved a variety of planning challenges. The architects designed the space to deliver a program for grades 7-12 based on the Project Lead the Way curriculum. This integrated curriculum assumes the presence of both special engineering classes and classes for English and mathematics classes that are related to an engineering focus.

The new laboratory is part of a newly built building located on the existing Fremont campus. The building is very spacious with high ceilings and large windows making it very bright. Some of the walls were deliberately left white and blank for displaying material through a projector. The engineering laboratory has mobile furniture that can be easily moved around the study space and is also adjustable for the convenience of students. The laboratory equipment includes 3D printers, a drilling machine, a panel saw and a CNC milling machine. This room is suitable both for individual work at the machines and for group project discussions. [7]

In the centre is a room for storing projects and materials, which works for both rooms and connects them together.

The design lab is on the other side of the warehouse and has perimeter storage and movable furniture for group work, presentations and various computer and design activities (Fig. 2).

Based on their pedagogical and technological features of STEAM-teaching and the considered examples of implemented educational spaces, it is possible to formulate the principles of organizing the educational space of STEAM-learning.
1. Mobility of spaces with free planning and transforming classes, where the teacher and students have the opportunity to organize the educational process independently. All laboratories and classes should be connected, or have a shared space – a hall for constant meetings and discussions.

2. High manufacturability of materials and active use of technologies – the use of innovative and low-cost energy-saving engineering solutions and thoughtful design.

3. Organization of an informal space for students, where they can independently work on an assignment or project outside the classroom.

All of the above principles of space organization work only with an integrated curriculum and an interdisciplinary approach.

4. Results
Educational spaces for the implementation of STEAM learning have the following characteristics:
- these spaces are intended for project activity, which is the main one in STEAM training;
- ensure the availability and active use of technology;
- implement lifelong learning, which implies working on a project outside of school hours in specialized and open spaces;
- designed for an interdisciplinary set of programs.

During the analysis of the implemented projects of educational spaces for STEAM training, the following principles of organizing the educational space for STEAM training were identified:
1. mobility of spaces with free planning and transforming classes,
2. high manufacturability of materials and active use of technologies,
3. organization of an informal space for students.

The principles obtained were applied in the project of the Art and Technology Lyceum in Novosibirsk to organize a STEAM space located in the architectural and art block (Fig. 3). At the request of the customer, STEAM-space is implemented for the module of information technology disciplines - computer science, 3D-modeling, prototyping and design activities. In the structure of the Lyceum, STEAM-space occupies part of the 3rd floor and is a single space divided into zones – study rooms for individual subjects and a central common hall with mobile furniture for project discussions (Fig. 4).

![Figure 3](image-url). Functional blocks of the building of the Art and Technology Lyceum in Novosibirsk
Source: authors archive.
Figure 4. The project of the Art and Technology Lyceum in Novosibirsk. Space-planning scheme of the lyceum, STEAM-space for the module of information technology disciplines

Source: authors archive

The common hall, if necessary, can become an area of communication or teamwork, it can be subject rooms. The mobility of spaces is achieved by a sliding partition between the computer science rooms, which can be used as two separate classrooms or as one ample space for holding a competition or developing a team project. Also, all the cabinets of the block are interconnected by glass partitions and doors (Fig. 5).

In the block of informatics and 3D modelling, there are computer classes with projectors and mobile TV panels, a design workshop adjacent to a class in 3D modelling and 3D printers, a laboratory assistant is equipped with workplaces for teachers and a place to relax. The interior design uses ecological materials, light walls with cork boards for the presentation of ideas or the process of discussion.

For independent work in the lyceum, there are coworking and recreation spaces with mobile partitions, which, if necessary, create a working area or a presentation area. Also, the library provides space for independent work and a small area for projects.
5. Conclusion

Modern learning technologies, such as STEAM learning, have a direct impact on the architectural and planning organization of the learning space. Successfully implement STEAM technology needs to create a unique learning environment that meets the conditions and features of this technology.

Architecture and pedagogical technology are interdependent. When designing any educational space, the set of pedagogical technologies and the form of teaching should be initially determined. STEAM training is based on the project method, active learning and the use of technology. Therefore, in the project of the Art and Technology Lyceum in Novosibirsk, special attention was paid to creating a mobile space with available zoning of the educational space, taking into account the building codes and regulations of the Russian Federation. Also, a large number of informal spaces were created at the Lyceum for students to work independently during off-hours.

It should be emphasized once again that a simulated space for STEAM learning only works with interdisciplinary projects and an integrated curriculum. Based on the formulated principles and the author's model of the Art and Technology Lyceum in Novosibirsk, it is planned to develop variable layouts of the main functional blocks of premises required for the implementation of STEAM technologies. Architects when designing new school buildings or educational grounds using STEAM technology can use this set of diagrams and particular recommendations.

References

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