Ergonomic Solutions of Facilities and Laboratory Work-Stands at Universities

Programming of Ergonomic Technological Lines – Case Study

Dorota Winnicka-Jasłowska

Department of the Theory, Design and History of Architecture
Faculty of Architecture, Silesian University of Technology
Akademicka 7, 44-100 Gliwice
Poland
Dorota.Winnicka-Jaslowska@polsl.pl

Abstract. The scope of the paper is the design of laboratories in consideration of modern technologies and modern manners of work: ways of shaping and arranging laboratory facilities, depending on the equipment and process technology. Following the introduction, the functional and spatial programming process of laboratory stands at the Faculty of Bio-Medical Engineering, Silesian University of Technology, devised by the author of this paper will be discussed.

Keywords: laboratory work-stand, universities, ergonomic solutions.

1 Introduction

Didactics, experience and research and development activities require new space. University R&D facilities are used for analyses on the didactic level, as well as research, development works and experiments conducted by the research and teaching staff. These functions are served by laboratories, located in faculty buildings and generally constituting a detached spatial zone, or in a separate building designed for research, development and laboratory works. The laboratory functions are usually essential for the following engineering disciplines: biology, chemistry, physics, but also biotechnology, bioengineering, medicine and related fields of science. Computer and telecommunication workshops frequently support specialist laboratories.

Modern laboratories look different than older facilities. Laboratories are generally associated with typical work- stands connected into technology lines and set in a specific sequence. In the face of technological and technical evolution and the advancement of new fields of science, modern labs have undergone a revolutionary metamorphosis, so their image is not the same as in the past.

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2 Modern Laboratories

2.1 Principles of Arranging Laboratories

Each discipline of knowledge and science has its own specific qualities, characterized by process technology of research and experimental works, special equipment and apparatuses and work procedures. The methods of laboratory work have a significant importance to the arrangement of laboratories; therefore, nowadays linear technology layout of the work-stands is not as popular as in the past.

There are three essential types of work applicable to laboratories:

- interactive work - involving teams and supported by computers
- experimental and individual work performed by one or two researchers at one work-stand, and
- experiment - empirical work carried out by students divided into groups and using one or several work-stands.

Hence, laboratory space should be adjusted to the type of activity and cooperation in the performance of specific tasks. The main objective of the design of laboratories is the provision of safety and efficiency of work at laboratory stands.

Modern R&D activity is nowadays supported by on-line computers, run concurrently with the performance of research work. Accordingly, contemporary lab stands must be enlarged to accommodate hardware. Likewise, modern specialist apparatuses and other equipment are very technologically advanced and used at all levels of research: starting with teaching tasks and leading up to well-developed R&D projects. Thus, in the phase of spatial and architectural programming of laboratories, the provision of sufficient place for apparatuses and supporting installations should be taken into account.

As already mentioned above, computers are indispensible tools of all types of laboratory space, including: generally accessible space of the laboratory, seminar rooms for instruction classes preceding or following laboratory experiments, and the space for specific R&D labs. Computers are used to control the operation of other equipment and apparatuses, to insert the data derived from the experiments, and to on-line cooperation with other work-stands.

Laboratories devoted to R&D projects may be placed in science teaching buildings or grouped in separate laboratory facilities. The space required for research is different from the teaching space, as it is destined to individual or small team work. Yet, the requirements for the mechanical and electrical equipment are very similar for both types of laboratories.

However, research laboratories vary, depending on the disciplines of science. For example, chemical labs require work-stands for each researcher equipped with fume tools. Biological laboratories need a proper stand with easy access to various types of apparatuses. Physical laboratories should have the equipment mounted to the floor and designed in consideration of enabling easy access to electricity and water.

Research laboratories should be adjusted to tasks performed by research teams under the supervision of the project manager, in terms of sufficient floor area. The teams should include 4-8 members. It is also important for the laboratory module to be reproductive and flexible to enable rearrangements of space.[1]

2.2 Supporting Space

Didactic and research works require highly specialized apparatuses and equipment for analytical and experimental tasks. This means that it is essential to provide supporting space in a room adjacent to the lab.

The requirements that such supporting rooms should meet depend on the discipline of science. For example, a chemical lab should be provided with the space for apparatuses placed on desks or on the floor. For the discipline of biology, rooms should accommodate large- size apparatuses, as well as additional desks for smaller equipment. Moreover, biological labs need rooms for cultivation or culture of bacteria, plants, etc. and prep rooms, as well as rooms for controlling the microclimate.

Currently, teaching syllabuses and the tasks that students are to perform need more space for research and education, not to mention space for the equipment frequently used in classes. Usually, such equipment is kept in storage rooms.[1]

The programming of supporting space is only possible when the design architect knows and understands the processes that take place in a laboratory, and insight into the manner of operating apparatuses and equipment to be used. In addition, it is important to consider the microclimate conditions for the supporting rooms.

3 Detailed Regulations Concerning the Architectural Desing of Laboratories in Poland. Work Safety and Hygiene

Buildings containing laboratory facilities should be constructed and maintained in compliance with specific technical and building regulations – and, in particular, as far as safety and hygiene of work is concerned.[3] Laboratory rooms should have identifiable safety exits to secure the evacuation from the building in case of safety hazards. They should be marked with symbols stipulated by the provisions of the Polish Standards.[4]

Laboratories should be supplied with the equipment preventing contamination or pollution with chemical substances. The provided installations should enable safety of operation and should not expose workers to electric shocks, fire hazards, explosion hazards and other detrimental impacts. The rooms in which hazards may occur should be clearly marked with warning signs – in compliance with the Polish Standards.

Laboratory work rooms should offer both natural and artificial light, appropriate temperature, air exchange and precautions against humidity, adverse heat conditions and excess sunlight. The height of laboratory rooms should not be lower than 3.3 m. The rooms where hazardous reagents and elements posing a threat to health and safety, should make use of the technical solutions that prevent their penetration to other parts of the laboratory. Work-stands should be protected against uncontrolled heat emission caused by radiation, conduction, convection, and the influx of cold air from the outside. Measuring and testing equipment that may release hazardous gases, vapors and dust should be air-tight. If this is impossible, they should at least have local exhausts. If substances hazardous to health may be released in the course of processes and if there is a possibility of ventilation failure, a warning system should be used. If mechanical ventilation with air circulation is installed, the quantity of fresh air should not be lower than 10 % of the total volume of the exchanged air. However, air recirculation should not be installed in work rooms where hazardous biological or chemical substances pose the hazards stipulated in the regulations on safety and hygiene of work concerning the presence of chemical reagents or materials emitting unpleasant or noxious smells, instant increase of the concentration of hazardous substances or threats of explosion.

4 Functional and Floor Area Design Program for the Laboratories of the Biological Engineering Faculty, Silesian University of Technology – Case Study

4.1 Objectives of the Architectural and Programming Task

The Faculty of Biomedical Engineering, Silesian University of Technology, was founded a few years ago. Initially, it occupied some buildings of the University campus. The creation of the new Faculty and new engineering disciplines of study was planned to be provided in modern laboratories and workshops; hence, the Faculty authorities applied for acquiring a new building, and ordered a programming study for new laboratories. The author of this paper devised initial functional and spatial program of the new laboratories.[2] The introduction to the task were pre-design analyses to define users' needs in consideration of a definite nature of the Faculty, specialization of its Departments and technologies of laboratory processes. As a result, ergonomic "ideal" models were created and model solutions for all the laboratories and workshops specified by the Faculty authorities, with the main focus on the principles of ergonomics, technologies of R&D processes and the planned equipment.

4.2 Description of Date Collection Method and Elaboration of the Design Project

The grounds and input for the research is the identification of basic groups of users and their organizational and social needs. The description of the Faculty's organizational structure with division into organizational units and the number of their users provided supportive material. Next, the users and their activity types were depicted, as well as their organizational needs and, what is of special importance nowadays: their social needs.

In the past years this factor was not taken into account in the design of university buildings. These days other fields of science, such as sociology and environmental psychology offer better insight into social issues and support architects in their design solutions, especially as far as human requirements, such as the needs of privacy and territoriality, isolation and cooperation are concerned. Students constitute the biggest group of university buildings users, with their specific needs that change the image of a modern university facility. An important element in the conducted research work was the consideration of students' organizational and social needs.

In the case of any design that will house an institution, it is essential to understand the objectives of its activity, modes of operation and planned or predicted organizational and technical and technological changes. Organizational changes are of great importance and they should translate into the manner in which space is shaped. Forecasts of further development of organizations such as university units, faculties etc. have an impact on design assumptions. Yet, it is spatial solutions that determine the efficiency of current and future functionality of a given organizational structure.

It is also vital to assume the number of users of the designed building. The quantity of the users is subject of change in the whole life cycle of the building: it may increase or decrease and change its proportions. Nonetheless, an approximation is important as it enables the formulation of a strategy of efficient space management of the facility, for example, if the number of students' declines, some class rooms, lecture rooms or even parts of the building may be leased.

On the other hand, if the number of students or teaching staff increases, some space reserves should be available, so that the surplus of space that occurred in some periods of the functional life of the building could be rented or utilized for organizing such events as conferences or exhibitions.

Another cognitive step in the discussed research is to determine appropriate teaching and learning conditions. The starting points are the curricula and knowledge of the manner in which classes, lectures and workshops for students are conducted. It should be remembered that every university, and even its particular faculties, have specific spatial requirements and functional types of facilities; beside class rooms, lecture rooms or seminars, there are others specific to a given field of study, such as laboratories or studios equipped with devices and aids typical of a given faculty.

In the case of the Bio-Medical Engineering Faculty these are laboratories and work rooms used by students during instruction hours and by the research and teaching staff. Each of the four Faculty Departments has its specialist equipment set-up in a specific technology line and having specific dimensions, which is very important in designating the size and proportions of rooms. Therefore, it was necessary to conduct the site inspection of the existing specialist facilities.

For each of the inspected facilities photographic inventory was carried out as well as general physical measurements taken. The required data included: basic dimensions- length and width, examination of the equipment and technology line, as well as information on the type of activity and manners of equipment use and operation.

The information was collected from interviews with the users (both university staff and students) and from the in-situ inspection with participation of all parties concerned. In each room photographic documentation was taken, which was helpful in making records of the equipment and its arrangement. The interviews also involved the assessment of the facilities in terms of size, functionality and equipment, enabling the formulation of conclusions valuable for devising an ergonomic model of an "ideal ´new room. The information obtained from university staff also included functional connections among laboratories and the sequence of their use in the teaching process typical of a certain study line, for example: seminars that introduce students to laboratory classes, in order to consider the functional need of their proximity.

During the in-situ inspection data on specific requirements and technical conditions that the facilities should fulfil was also collected: micro-climate, lighting conditions (exposure to sunlight or location oriented to the north due to the need of providing lower temperature and elimination of the access of sunlight, or additional lighting of work-stands, etc.), allowable noise emissions levels and vibrations (evoked by some equipment, as well as their potential negative impact on other precise apparatuses, for example on electronic microphones), allowable ambient temperature, ventilation, air-conditioning, etc.

Detailed interviews with the teaching and research staff were conducted to obtain information necessary for designing new laboratories and work rooms, to enable precise determination of the technological aspects of work stands and the space required.

After the analytical and data collection phase, the next step was focused on devising ergonomic models of "ideal" new rooms. On the grounds of information and criticism derived from the staff it was possible to devise best solutions concerning the spatial arrangement and square area of the planned facilities, taking into account the modularity of the facilities to facilitate the transformation of schematically drawn solution to specific design solutions.

Next, focus meetings were arranged with the university staff to discuss the proposed solutions of laboratory functions. Such meetings are held in small groups consisting of carefully selected people who can contribute to the rectification of the proposed solutions. Staff members representing the four Faculty Departments also actively participated in the process of devising model solutions concerning office space and facilitating the adoption of the most suitable ones in terms of the Faculty's organizational needs. Stage I was finalized by correcting the drawings and schemes and preparing the draft of the program.

4.3 Results of the Analyses

The final elaboration included Check-Lists for each laboratory in view of: the inventory of the existing conditions, specific requirements and graphic model solutions. In the case of completely new laboratories, the Check List contained complete information on the apparatuses, with their dimensions and photographs and graphic presentations of model solutions. Thus, the elaboration comprised a set of the preferred laboratories, and input material for the subsequent design concept. Before the concept emerged, the elaboration helped the new Faculty to decide whether the new laboratories could be arranged in the buildings offered by the University authorities and adjusted for the needs of the Faculty of Biomedical Engineering. Accordingly, thanks to the elaboration the optimal surface area of the laboratories was defined.

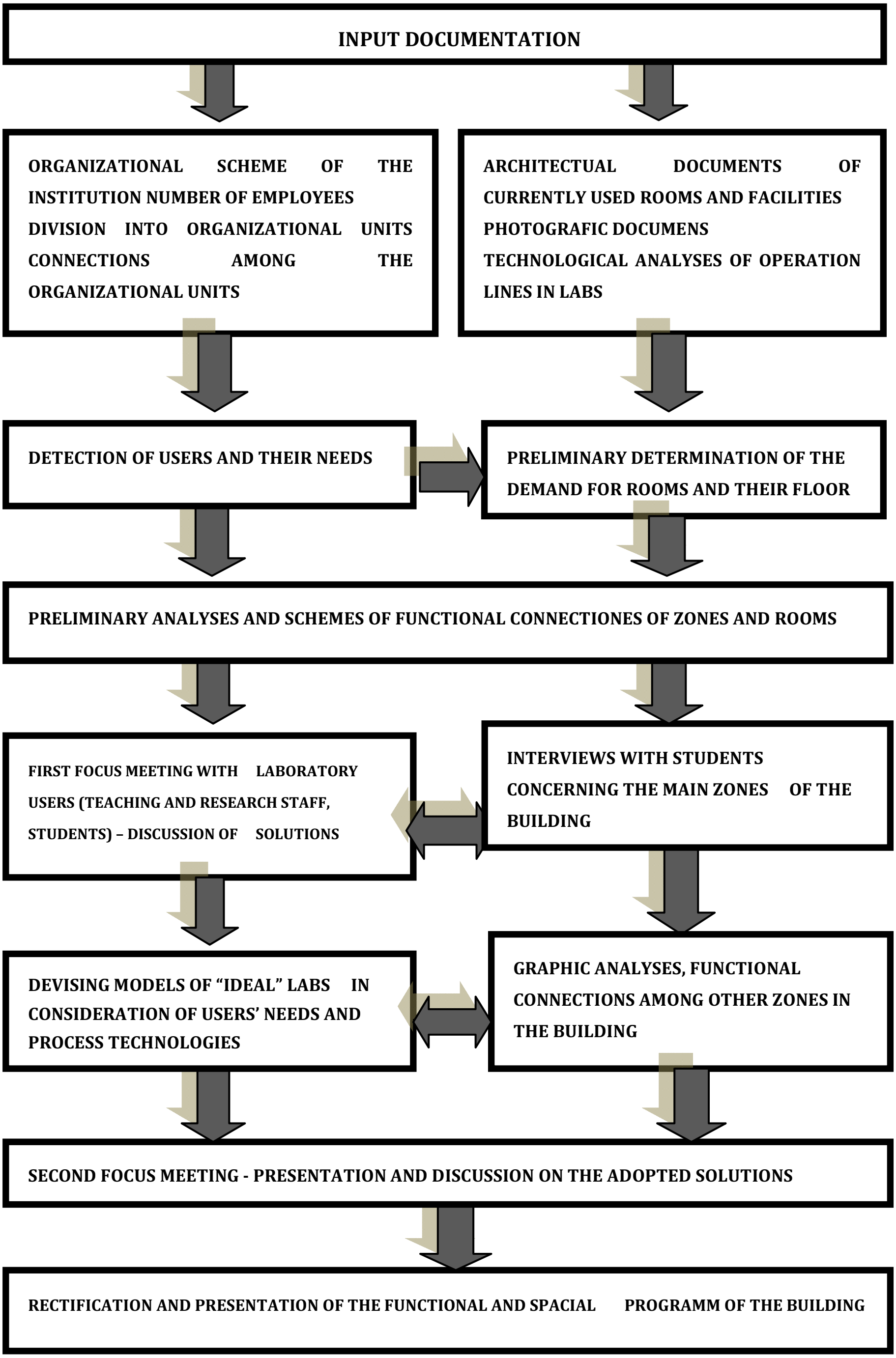

Fig. 1. Research Project Diagram. (Author: Dorota Winnicka-Jasłowska)

5 Conclusions

The detection of the functioning rules of a future building in consideration of didactic, research and development and social processes that it houses contributes to the formulation of elaborate functional and spatial program for the newly designed building. The complexity of laboratory technologies utilized by particular Departments requires profound pre-design analyses, without which it would be practically impossible to design the research and laboratory zones that make up essential parts of the Faculty building. The visits and in-situ inspections in the existing Departments explicated and enabled the understanding of the essence of the processes involved in the teaching and research activities of the Faculty staff. Interviews with the Faculty staff also indicated different modes of student instruction in comparison with, for example, the Faculty of Architecture, specific to the field of study, which, surely, have a definite impact on the shape of the interior space and functional solutions (for example: location of seminar rooms in the vicinity of laboratories. Accordingly, it may be concluded that every type of a university and its particular faculties should fulfill the requirements specific to a given field of study. Thus, design templates cannot be used. This applies to the majority of functional zones and types of rooms in university facilities, as substantiated by all analyses of existing university buildings carried out by the author of this paper, revealing frequently occurring errors in the understanding of specific features, field of study and the associated activities. The pre-design analysis discussed in the paper was also made to "try out" data collection and processing methods and to propose and select best solutions.

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