

## Modern, certified building automation laboratories AutBudNet – put “learning by doing” idea into practice

**Streszczenie.** Idea „Nauczanie przez praktykę” to innowacyjne podejście do nauczania studentów kierunków technicznych. W niniejszym artykule przedstawiono prace i badania w tym kierunku, realizowane w wybranych polskich uczelniach technicznych, a związane z praktycznym nauczaniem automatyki budynkowej laboratoriach sieci AutBudNet. Każde z nich bazuje na odmiennym standardzie międzynarodowym – LonWorks, KNX, BACnet. Większość opisanych prac realizuje się przy aktywnym udziale studentów studiów magisterskich II stopnia. (Nowoczesne laboratoria automatyki budynkowej AutBudNet – realizacja idei “Nauczanie przez praktykę”).

**Abstract.** “Learning by doing” idea leads to improvements and innovations in students learning, especially in engineering fields. In this paper activities and works conducted by some of Polish technical universities are described. They are connected with learning of building automation systems in new laboratories’ network – AutBudNet. Each of the laboratories base on different international standard – LonWorks, KNX, BACnet. Most of the research are conducted with special, active participation of selected senior years’ students from courses leading to a master’s degree.

**Słowa kluczowe:** automatyka budynkowa, LonWorks, KNX, integracja.

**Keywords:** building automation, LonWorks, KNX, interoperability.

### Introduction

Building automation systems are one of the fundamental elements of modern buildings’ infrastructure, especially public and commercial. They are base for Building Management Systems (BMS), providing control and monitoring of all essential subsystems in this kind of buildings – from comfort to assets and persons security. Last few years particular emphasis is placed on the optimization of heat and electrical energies consumption as well as improvement of buildings’ efficiency. It is new field for building automation systems implementation in connection with smart metering idea, low-energy and passive buildings projects etc. Building automation systems are ideal tool and solution to realize them [10]. From this point of view it is appropriate to educate high specialists in this profession, but apart from general knowledge about electrical and ICT installations in buildings, they should acquire skills in build and organization advanced control and monitoring systems. It would allow them to propose new functional integration and optimization scenarios for different subsystems in buildings, for example HVAC, windows opening, access control etc. [5, 11]. Acquiring and reinforcing this kind of knowledge and abilities are possible only by practical works, direct contact with real installation and nodes, control and monitoring systems. It should be provided by modern laboratories or experimental rooms, buildings, with implemented BMS installations. It is of course great challenge for technical universities and their research workers to propose and create this laboratory base and appropriate modern teaching programs [9]. To date, experience in this field are different. One of the methods is organization of demonstrations in real buildings, but they are restricted. Usually students have no possibility to direct contact with control panels or integration tools, since buildings have been integrated already and their user have no access to these kind of tools. So they don’t allow to touch nothing regarding to security [1]. Second method, most popular in many industrial and building automation laboratories, are presentations led by teacher/trainer on laboratory standings for small students’ groups. And again – role of students is usually passive, sometimes they read results, data or set settings for some devices, but only according with instruction and teacher permission [2].

These methods could be justified only for first years of studies, but on senior years it should be changed. Students have to play active role in education process, but it is difficult to organize “real active” classes for all of them. It was the source of idea to conduct some master’s thesis

with selected students. This way they have opportunity to realize specific integration and optimization tasks, create themselves innovative solutions and methods of work, with experienced research workers support. The laboratories equipped with appropriate systems’ infrastructure, devices and subsystems are aids and tools to do it. First experiences connected with realization of mentioned idea in AGH-UST LonWorks Laboratory are described in this paper.

### AutBudNet – network of laboratories

As it has been mentioned before, those kind of classes and researches should be conduct not only in “hermetic” laboratories, but on “live organism”. Therefore many of technical universities in Poland have been started organization their own didactic and research base along with building/building’s parts modernization and conversion into automated objects, equipped with latest devices, sensor and controllers, based on international standards. It creates opportunity to teach essential engineers resources, with right level of knowledge and conduct research - testing new solutions, algorithms, methods. Quite often these activities are financed by European funds and ministerial grants [6, 7, 8].

In Poland in 2007 the All-Poland Science and Industrial Consortium for Energy-Efficient Technologies and Building’s Electrical Installations (SICETBEI) was established. The members are universities and companies:

AGH-UST (University of Science and Technology) Krakow - consortium leader

- Gdansk University of Technology
- Technical University of Lodz
- Poznan University of Technology
- Schneider Electric Polska (former MERTEN Polska)
- ZDANIA Sp. z o.o.

In period 2009 - 2011 some of the SICETBEI members realised R&D project “Certified Laboratories Network for Energy Efficiency and Building Automation” - AutBudNet. It was a part of Operation Programme - Innovative Economy. AGH-UST, Poznan University of Technology and Gdansk University of Technology took part in this project. The main purpose of the project was building of three research centres, adapted for assessment of devices, sub-assemblies, building automation systems and buildings’ energy efficiency, based on three international standards: LonWorks, KNX and BACnet. In the years 2010 and 2011 new laboratories were certified and became centres of standardization and professional examinations. In

particular, AGH-UST centre of LonWorks technology, has qualifications: LonMark Product Certification (devices, products) and LonMark Certified Professional (integrators). Research and professional trainings programs have been preparing for all those laboratories. They are connected

with implementation of energy efficient technologies in buildings. Those three centres create network called AutBudNet [6]. Figure 1 present locations of the centres in Poland.

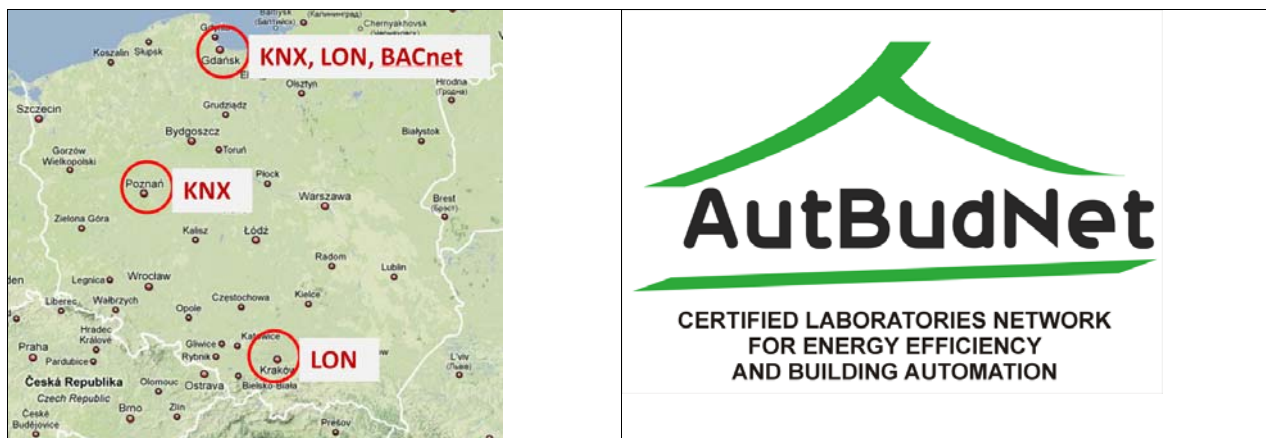


Fig. 1 - Locations of the AutBudNet laboratories and logo.

#### Poznan University of Technology - KNX centre - review

The KNX Laboratory is situated in detached and modernized building of Institute of Electric Power Engineering in Poznan University of Technology. This building has its own, independent power supply line and heating supply. It has been equipped with modern KNX nodes and installations, extensive meters, modules of monitoring and remote, outside control, so it could be object of research in reduce electrical and heat energy consumption. Electric installation in building has been divide in some separate circuits with independent energy meters, to research energy consumption by individual groups of loads. Apart from that, it is of possible to control and monitoring lights, radiators, blinds and access over automation system.



Fig. 2 - KNX Laboratory in Poznan – laboratory standings

Laboratory standings in the rooms allow to conduct research on all kinds of devices, compatible with KNX standard. Research workers and PhD students could design and test heat control systems, research influence of different solutions on energy consumption and efficiency in buildings. They conduct research on development and improvement KNX technology security, like assessment of the most often threats appeared in the system and devices as well as preparing effective methods how to prevent them. Another field is testing of the KNX devices and rules of integration building installations as well as subsystems with automation modules and security systems, which could use KNX standard [3, 4]. On Figure 2 view of the laboratories is presented.

#### Gdansk University of Technology - integration centre - review

In Gdansk the Laboratory of Management and Integration of Building Automation Systems has been built. It is located in one room of the main building of Faculty of Electrical and Control Engineering. There are four laboratory standings there:

1. KNX technology - with set of the basic actuators, sensors and system modules
2. LonWorks technology - with set of basic elements and devices
3. BACnet technology - with system controller, application controller, network sensor and peripheries
4. Management and integration standing, equipped with modules for communication between KNX, LonWorks, BACnet devices and other meters, sensors with popular interfaces - Modbus, M-Bus.

In the laboratory research workers and students work out new devices and methods for efficient and reliable integration of all international building automation standards' devices, with different communication interfaces. They conduct research of tools for maintenance and management advanced building automation systems. It is possible testing interoperability SCADA and BMS software with different devices and building automation standards as well. It will be conducted research of functional security and reliability applied solutions. Part of the laboratory from Gdansk is presented on Figure 3.



Fig. 3 - Laboratory of integration in Gdansk - laboratory standings

### AGH-UST - LonWorks laboratory - review

In AGH-UST in Krakow three research laboratories have been established. The rooms are equipped with installations and nodes to control and monitoring advanced buildings' infrastructure systems including: HVAC system, lighting, blinds, access and DVR system, photovoltaic panels, solar energy collectors, electrical and heat energy consumption monitoring as well as fire-alarm system monitoring. All subsystems are controlled by integrated building automation system, based on PN-EN ISO/IEC 14908 (LonWorks) standard and this way laboratory rooms and their infrastructure have become real object to conduct research, test and assessment influence of LonWorks systems on functional and operation characteristics of the buildings.

As it was mentioned before, there are three laboratories there:

1. Laboratory for research of devices and systems conformity with LonWorks standard (called - Conformity Lab)
2. Laboratory for research building automation system's actuators (called - Actuators Lab)
3. Laboratory for research of LonWorks devices and systems influence on buildings' energy efficiency (called - Influence Lab)

First of them - Conformity Lab - provide possibility to conduct research of devices and systems, paying special attention to their conformity with LonMark standard. This laboratory has LonMark International Association accreditation in the field of products and devices LonWorks certification (ISO/IEC 14908-1 standard).

The second one - Actuators Lab - has been equipped with paying special attention to testing and researching of functionalities all kinds of devices dedicated for building automation systems and subsystems: controllers, I/O modules, actuators. It is also possible to test devices interoperability, with respect to communication interfaces and dedicated software.

The last one - Influence Lab - will be used to conduct research of possible influence different devices and whole building automation installations on energy efficiency in buildings, on electrical and heat consumption savings and possibilities to improve users comfort. Picture from one of the laboratory room is presented on Figure 4.

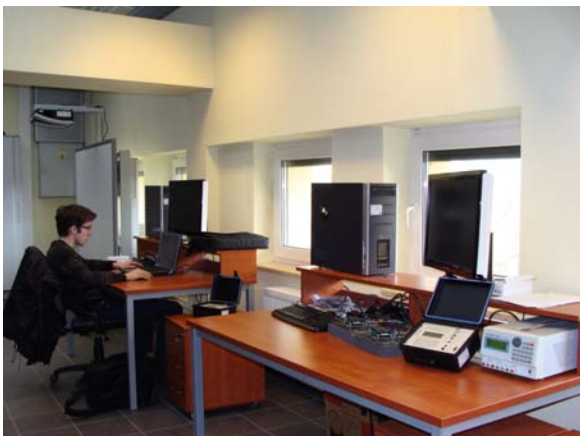


Fig. 4 - LonWorks laboratory in AGH-UST Krakow - Conformity Lab

Fundamental purpose of those laboratories is solution some essential research questions, connected with building automation technology development and its possible applications in modern, new and modernized buildings. One of them concern on working out research methodology for assessment influence building automation systems on energy efficiency accordingly with PN/EN 15232 standard. The second one concern on another problem: drawing up

energy efficiency research methodology for comfort control modules applied in public buildings, according with PN/EN 15500 standard (energy quality and efficiency criteria). In those laboratories it is possible to carry out projects connected with automation modules and devices design, accordingly with mentioned standard PN/EN 15232 and formulation of guidelines to right devices design to meet PN/EN 14908-1 standard requirements [6].

### **AGH-UST LonWorks Laboratory – control and integration concepts**

As it was mentioned before AGH-UST LonWorks Laboratory consist three rooms - total area 244 m<sup>2</sup>. The rooms are equipped with all installations for control and monitoring lighting, blinds and windows (electrical control), HVAC (air condition, chillers, humidifiers, radiators) and access control. Additionally it is possible to integrate control system on the monitoring level with subsystems like: fire extinguishing, video monitoring, remote reading of electrical and heat energy meters, monitoring of solar collectors parameters, monitoring PV panels' parameters. It is also possible to monitor temperature, pressure, difference of pressures and CO<sub>2</sub> concentration, connected with comfort in the rooms. Setting of parameters and basic control are possible by classic switches, cooperating with binary inputs modules and touch panels L-Vis. Thanks to them, for different algorithms, it is possible to control individual devices or subsystems as well as groups of devices, integrated subsystems etc. The touch panel module is additionally used for graphic visualization of sensors and actuators state. The whole building automation system in AGH-UST laboratories based on one of the international standards - PN-EN ISO/IEC 14908 (LonWorks). It allows to use infrastructure of the laboratory rooms as real object to study functionalities and LonWorks technology impact on use and operation of buildings. It is possible to test different control strategies, integration and functional optimization algorithms or use the laboratory BMS data as example of data from real object with advanced infrastructure. With so modern, well equipped and non conventional organized laboratories, it is also possible to organize different kinds of research Works, both on laboratory standings with their devices as well as devices connected and integrated in BMS infrastructure of laboratory rooms. In long term perspective it creates very good platform for technical education, oriented on practical skills and knowledge use in practice. It is extremely important for engineers. Currently, in the first stage of laboratories functioning, research and development works are focusing on integration of basic laboratories' infrastructure functionalities. Some of them were entrusted senior years students from Industrial and Building Automation speciality as their thesis. This way they have opportunity to expend their engineering curriculum by practical solving of real research problems and creating different control strategies. This idea evoke huge response from students; they are interested in those possibilities to realize their thesis and acquire so valuable practical skills by new way and method. The main difference arising from commune with real control and monitoring infrastructure in real rooms/objects. Students may integrate selected subsystems and their functionalities like: classical light and temperature control, HVAC devices and systems, access control, blinds etc. Some of propositions, ideas and results from realized thesis, along with some specific technical problems examples, are described in the next part of the paper.

### **Students' works**

To date, during last two years, three thesis were realized. They were connected with use and integration

different kinds of devices and subsystems, mentioned before. First of them was dedicated to start and organize basic functionalities, essential from laboratories usage point of view. Substantial majority of the solutions from it is still used. Two subsequent theses were based on the first one. They extended it with new, more advanced functionalities from another subsystems.

**Thesis 1** As it was shortly mentioned before, main assumptions for this project concerned idea of organize and integration control modules, actuators, sensors and switches for lighting, blinds and windows in the laboratory rooms. These works, conducted with research workers support, have been essential to provide basic functionality and comfort in them, to optimize and facilitate control process for laboratories users. Students had proposed and then have realised appropriate control algorithms along with connections between switches, touch panels and some of sensors, integrated in the BMS system. As the result it is possible to select different light scenarios, control of the blinds position and opening/closing electrically controlled windows. To monitor and control all these functions, some panels for touch panel L-Vis have been worked out. Two of them are presented on Figure 5. It is of course possible to control mentioned functions by “classic” switches as well.

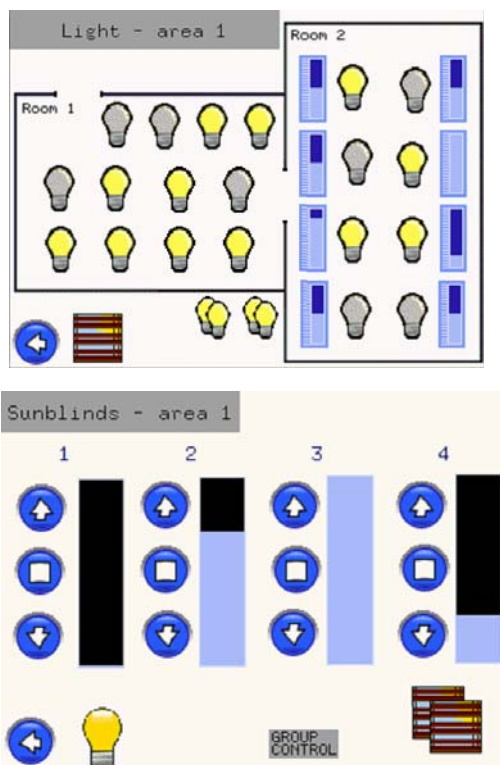


Fig. 5 - L-Vis touch panel screens

During their works students displayed considerable inventiveness to create their own control and monitoring concepts as well as proposed methods to solve technical problems connected with devices commissioning and integration procedures. It has been the first signal and evidence for rightness of idea to engage selected students into laboratory and research works, for practical works with building automation systems. Therefore research workers from laboratory decided to continue this conception in successive years.

**Thesis 2** Another thesis has been dedicated to development of most advanced functionalities for lighting, blinds, sensors and temperature control. Based on previous thesis student has proposed some conception changes and development of integration idea for those subsystems to

improve comfort and usefulness in laboratory rooms (new light scenarios, “intelligent heating” idea – described later). He has carried out windows and blinds state visualisation system (see: Figure 6), based on BMS interaction with popular reed relay sensors, connected to binary input/output modules. This way by additional screen on touch panel L-Vis it is possible to monitor open/close states for windows and blinds in the laboratory rooms.

Additionally schedules for automatic light and radiators valves on/off control have been drawn up. For example – at winter all radiators are controlled automatically, but it is possible to change settings manually on user demand.

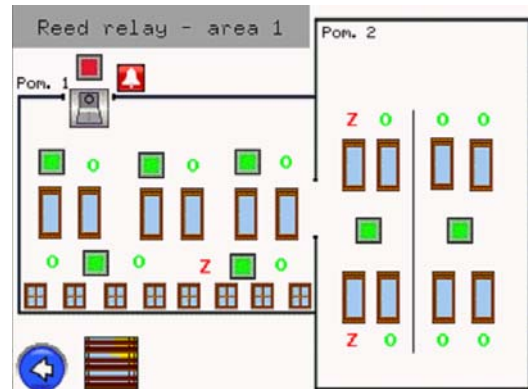


Fig. 6 – L-Vis touch panel screen – windows' state

**Thesis 3** In third thesis students have been obligated to propose and implement algorithms to control HVAC subsystems, with interaction between them and humidifiers, classic radiators (under windows) and windows state monitoring system. On account of high number of variables and parameters available in HVAC controller, the first stage of works concerned selection the most important control and monitoring signals, essential to carry out proposed control conception. It is based on two modes of air conditioner running. The first one – automatic temperature regulation – consist in keep constant temperature in the rooms, based only on one parameter directly set by user by touch panel. It is simplest mode from the user point of view and could be used without specialist knowledge about HVAC systems. The second mode – ERS mode – with extract air temperature-related to supply air temperature regulation, gives user more advanced HVAC systems control. Settings for this mode are available on touch panel L-Vis as well. Screens are showed on Figure 7.

To save electrical energy function “night cooling in summer” has been used by students, allowing to cool rooms at night. Based on mentioned two modes, schedulers of HVAC running have been prepared to full automatic heating and ventilation laboratory rooms. Students worked out graphical interface to monitor, control and set parameters for HVAC system, integrated and consistent with previous thesis/projects. This way easy and user-friendly interface has been created, allowing to monitor parameters and settings for HVAC system as well as change settings and schedulers of running for air conditioners and humidifiers. Furthermore HVAC system has been integrated with other subsystems of windows and blinds state control and monitoring. It is element of mentioned earlier “intelligent heating” idea. For example, if any window in the room would be open longer than 1 min., air conditioner reduce its revolutions and valves on radiators in this room are going to be closed. Like in two previously described thesis, students have been very engaged into their works, have solved some typical as well as untypical problems and acquired practical experience.

This academic year another student has been starting carry out next thesis, dedicated integration of access control and energy consumption monitoring subsystems. He has been preparing conception of available functionalities using, their connections and integration with earlier carried out algorithms and subsystems integrations. Already, at the first stage of work, student has been totally committing to his works, undertaking new challenges and cooperating with research workers and thesis supervisor.

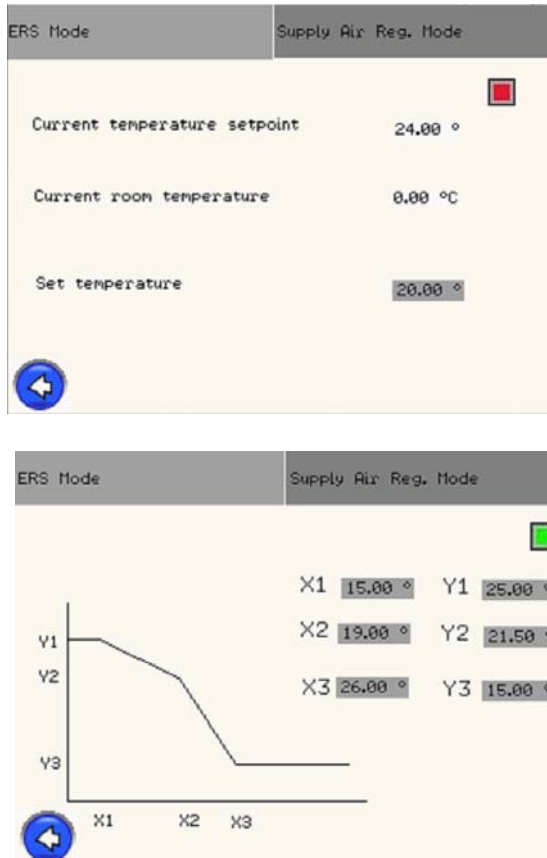


Fig. 7 - LVIS touch panel screen – HVAC control – two modes

## Conclusions

All works and projects described in the paper, show one of possible way to carry out “learning by doing” idea with students. Research and development works conducted in the laboratories, sign high potential to engage students (with theoretical knowledge) in practical works. They are interested in those kind of activities and more than once proposed their own solutions. Direct contact with technical and functional advanced devices and building automation systems, give them chance to acquire essential experience. Some problems and difficulties during works, mould skills in solving most popular problematic questions, connected with functional integration, available different communication media, monitoring and visualisation systems organization. Since the students groups are limited, research workers have opportunity to individual contacts with them and this way better support – theoretical and practical.

As it was mentioned before, activates described in this paper are first stage of laboratory development, concerned on R&D field. It is result of project specify – connected with R&D base development. At next stages in the future, when it will be possible to conduct laboratory classes there, more students would used modules on the laboratory standings etc. [2, 5, 9]. But always some better students will be

selected and engaged for more advanced research and integration works, preparing their MSc and PhD thesis.

All thesis presented in the paper had been defended with the best marks and one of the graduates is PhD student now (subject: automation; speciality: building automation systems). Another one is research worker and co-author of this paper. He has been working in the AGH-UST LonWorks laboratories. It is very clear sign that all mentioned activities are reasonable and needed [2]. It also motivate research workers team to intensify their activities to create opportunities for more active role of students in the research, especially in the next projects context. They are connected with determine possibilities to use building automation systems as a tool for remote heat and electrical energy consumption monitoring as well as other media, parameters, data etc. Another interesting field of BAS using is electrical energy consumption optimization and buildings' energy efficiency improve. But it requires to work out appropriate rules of devices integration and algorithms of different subsystems control. They should be tested and confirmed in real objects - rooms, buildings, installations. It creates new possibilities for research workers and students activity, to gain practical knowledge - so important for them, especially in engineering fields.

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