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ENHANCED FUNCTIONS OF TEACHER DURING THE PROBLEM-BASED LEARNING EVOLUTION (BASED ON THE EXPERIENCE OF THE EUROPEAN UNIVERSITIES PARTICIPATING IN THE TEMPUS MEDIS PROJECT)

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Виявлено основні функції викладача на різних етапах розвитку проблемно-орієнтованого навчання (ПОН). Показано, що вимога підвищення ефективності навчання студентів в області проектування промислових систем управління призводить до істотного розширення і ускладнення ролі викладача в навчальному процесі. Реалізація сучасних підходів до впровадження ПОН багато в чому спирається на чітке розуміння функцій викладача в залежності від рівня впровадження ПОН.
***Ключові слова**: проблемно-орієнтовано навчання, просунуте проблемно-орієнтовано навчання, реальне проблемно-орієнтовано навчання, ітерація, Agile методологія*

In modern conditions the training effectiveness increase relies mainly on the problem-based learning (PBL) methodology implementation. The article reveals the basic forms of PBL evolution and corresponding teaching staff functions. The study exposed detailed features of teacher role at each of the PBL stages methodology development on the example of teaching the industrial control system design. Taking into account these features will allow making the more accurate choice of the desired model for PBL implementation in teaching and learning process and preparing the relevant methodological support. Due to the teacher role complexity increasing with the PBL development the need for further training of instructors in the PBL methodology as well as in the relevant subject area is underlined.
***Keywords**: problem-based learning, advanced problem-based learning, real problem-based learning, iteration, Agile methodology*

1. Introduction

Initially, the problem-based learning (PBL) was introduced in medicine field [1]. Improvement in medical student training efficiency led to the rapid spread of PBL methodology to the other areas of knowledge [2, 3]. In particular, PBL is widely used in teaching of the modern industrial control system design subject [4–7]. Since the teacher's role is central-positioned in the training (inclusive training according to the PBL methodology), it is extremely important to study the teacher's functions in the PBL evolution, that will allow more clearly realizing the PBL methodology and also find further ways to improve the student training efficiency.

The characteristic feature of information society consists in the constantly widened gap between the school leaver knowledge and the university graduate knowledge required to start their work at the modern industry workplaces. Moreover, this gap has a natural character due to the fact that school leaver should have a wide range of knowledge in all disciplines while the modern production plants are characterized by intensive introduction of new technologies, robotic equipment and increasingly advancing software.

The situation is exacerbated by the fact that, coming to an enterprise, university graduate will not only possess up to date knowledge and skills, but he/she also should be ready for the continuous improvement of those skills throughout the work, so far he/she will be trained to self-adapt to the continuous hard- and software improvement.

2. The traditional methodology of teaching

Up to 90^{ths} of the last century, the issue of university graduate level non-compliance to the industry requirements was not of such an acute actuality, the widely used traditional methodology of teaching, completely meeting the industry needs can be characterized by the following features [1]:

1. The main role in teaching process is given to lectures.
2. The subject is divided into separate topics that are studied in sequence, only a small emphasis on their joint applicability being made.
3. The laboratory works, practical classes and course projects relate to the individual topics and are of secondary importance.
4. The central role is attributed to the teacher as a source of academic knowledge.
5. There are a large number of students in the group (25–30 persons).
6. The main method applied to assessing knowledge on the subject is an exam.

As a result, students had an extensive academic knowledge, including narrow range, which will be used by them in the specific industrial branch or enterprise. Up to 90^{ths} of the last century, it was enough for adapting to the current level of hard- and software for a reasonable time.

When using traditional methodology, the basic function of a teacher was to act as a source of academic knowledge, which was delivered during lectures. At practical workshops the students fixed skills of calculations based on the studied laws and principles. The aim of the laboratory work was to illustrate the theoretical material of lectures with practical reproduction on the laboratory bench.

3. Problem-based learning

Due to the industrial automation intensification in the 90^{ths} of the last century the traditional methodology became insufficient to provide the graduates required levels and PBL became wide implemented. In contrast to the traditional methodology, instead of wide-deal knowledge a narrower specialization became popular with emphasis on such key point as cases solving. This approach is characterized with the following features PBL [1–3]:

1. The main role in the training process is given to the cases (problems) solving.

2. The lectures are not given at all, or their number is small and they expose only the topics related to the specific cases.

3. The subject content is not divided into topics but it is integrated into the problem-oriented cases.

4. The central role is shifted from the teacher as a source of knowledge, to the tutor, who only monitors the process of case solution and when appropriate, tutor orients the process in the right direction.

5. Classes are held in small groups.

6. The knowledge assessment runs not in a one-stage exam, but it is integrated by nature being carried out in the course of case solving.

In contrast to the traditional methodology, the PBL makes emphasis on independent knowledge acquisition by students as a result of cases solving. In addition to the direct knowledge acquisition the students acquire skills of self-training while their future professional activity is running. The cases solving from the initial problem formulation to the readily solution getting is also important. It allows students to generate exactly that set of academic knowledge, which allows arranging the problem solution process from the task statement up to the practical implementation stage.

For the successful use of PBL methodology the teacher function of academic knowledge source is no longer enough. Now he/she has to control and direct, if it is necessary, the case solving process. The teacher not only conveys the knowledge, but points out, how and where to find information and how to use it to for case solving. Comparing with the traditional methodology, here the teacher's functions are expanded due to the task of finding the optimum case solution speed under students' maximum autonomy in case solving. The teacher directs student independent work, and they, holding regular discussions within the groups will divide the problem solution into separate issues by themselves, finding data necessary for those issues solving and then combining the results into a global problem solution.

4. Advanced problem-based learning

The next further stage in the training efficiency optimization was the division the PBL into the advanced problem-based learning (APBL) [8], and the real problem-based learning (RPBL) [9]. The APBL increasing of teaching effectiveness is due to a parallel study of several related disciplines and cases that can be solved using different sets of hard- and software. Students assimilate the cross-disciplinary understanding links and skills to select the best possible option. Comparing to the PBL the teacher's role in the APBL is essentially complicated as required to synchronize several teachers work, every exposing the taught subject and supervising the solution of cases based on the related subject material knowledge. Using the APBL methodology involves consideration of the main solution offered by some separate subject tools, as well as a comparison with the solutions offered by other subjects, and getting the complex solutions that provide the greatest effect.

Compared with the last century's early 90ths the complexity, range and capabilities of software and hardware for control systems building now are substantially increased. This, first of all, caused the need to improve the PBL efficiency, and, secondly, determined the APBL implementing the next features [8]:

1. Consistent development of skills with the necessary software and hardware.

1.1. Each elementary mean, representing a typical component of a large control system will be pre-mastered in isolation from the others.

Students must learn not only how to use this tool functionality in the designed control system overall algorithm, but also how to test it separately and as a part of a system including a large number of similar tools.

1.2. The gradual building-up of hardware and software to the complete system building.

Every new single extension must be tested for correct operation of the resulting tools set. Increasing the number of system components must lead to a new and improved quality of the system functioning. A particular attention should be paid to system safety and survivability when single and multiple failures of individual units appeared.

2. Teaching students to work with technical documentation.

Equipment and software applications became so complicated that individual components and programs functionality description takes up to thousands of pages. Students must learn how to quickly find the necessary information in the technical sources for enabling the required functionality on the basis of a common understanding of the software and hardware tools organization structure and respective documentation.

3. Case solution is made on the basis of the design and simulation environment use, this media is an important tool for control system building.

Currently a large number of auxiliary software has been developed, allowing multiple acceleration of control system design with an increase in their reliability as well as the designer ability to operate such sophisticated complex systems.

4. Developing the student ability to use sample programs and techniques provided by the soft- and hardware manufacturers, as well as by the producers of development environments.

The hardware and software features are quickly expanded and improved. Options for these tools use in the control systems design are in the first hand worked by their developers. Using these programs and application technique examples enables designers rapidly to develop the control system facilities with building on their basis effective systems that are at the forefront of modern technology.

5. Student training to develop technical documentation for the obtained case solution, like the presentation

of the immediate results and the final solution, as well as a reasonable argument the correctness and effectiveness of planned and produced actions.

Besides synchronized actions of teachers involved in complex subjects teaching, the teaching methodology also varies considerably. In APBL the teacher's function is less tutorial but is like to the "stalker" that is a guide man. The modern control system development is carried out through a variety of design environments which constantly updated and having greater functionality, thus requiring serious efforts for their mastering. In contrast to the use of certain software and hardware that can be initially studied in isolation, operation in development environments requires to pass all the way from the project creation to its completion. Therefore, the teacher's role of a "stalker" involves initial training of students how to pass this way using one of the possible options. Once students mastered the basic techniques for working with the development environment, they can, during case solving, implement their own further possibilities designing environment. Thus, in dealing with cases solving students are not only taught the construction of modern control systems, but also they master the design environment.

5. Real problem-based learning

In accordance with the APBL methodology to ensure the highest possible completeness and flexibility of training process all cases are educational ones. However, for the graduates' success at the enterprises they still need to learn the control systems development peculiarities at real companies. Each company's main objective is the production of competitive products, but not the additional training of university graduates. Therefore, the universities are complementing the APBL with RPBL training methodology. Since the RPBL encompasses the training cases solving, then, to adapt university graduates to the conditions they will face at real companies, the complex methodology relies onto basic program studies on the educational cases basis.

The main RPBL principles are as following [9]:

1. A real control system for a particular company is designed, subjected to further testing and commissioning.
2. The delay between respective task stating to the result commissioning should be as concise as possible and must not exceed the educational process time.
3. The goal includes such task as to exceed the technical and economic parameters and functionality of the known industrial analogues.
4. The resulting solution should be worked out as much as possible for further distribution and commercial realization.
5. The options for respective system further modernization should be worked out after its commissioning, or the variances of similar systems next generation development.

Naturally, in the RPBL, as in the APBL due to their peculiarities' use, the basic principle of students' work on the project in the PBL frame is strengthened: an active mutual cooperation. Just as in the PBL the teacher task is to achieve the following objectives:

• Improving the students' team work skills,

• Dynamic allocation of work volume among all members of the group,

• Each member of the group performs his/her part of the work, but all students need to master the technology of work and the results achieved by each of them,

• Maximizing the result from cooperation with the experts and project customers,

• Collaborative decision-making on control system design.

From the organizational viewpoint the project implementation is carried out by using the Agile methodology [10], modified for the development of real control systems as part of the teaching and learning process. The entire time interval, scheduled by the curriculum for control systems design is divided into individual steps, lasting one or two weeks. At each stage end a complete hardware/software that implements one or more of system functional is expected to be got. The resulting product is provided with relevant documentation further becoming part of the final documentation for the entire system.

The extremely important components of each stage are the comprehensive discussion of the results obtained and the current project status in terms of principal policy selection on the used hardware, software, algorithms including:

1. Intra-team project discussion (involved students group).
2. With the participation of specialized teachers who act as experts.
3. With the participation of leading experts from industry, cooperating with the university within RPBL.
4. With the participation of leading specialists of the customer having ordered the control system.

In contrast to the similar discussions held at the enterprise, limited by commercial confidentiality considerations, the RPBL supposes maximum openness and public discussion, contributing to the achievement of the maximum technical and economic efficiency of the planned system with the use of the latest achievements in the industry. Moreover, the customer's experts, based on the results obtained and the current needs of the enterprise can alter the control system requirements. The discussion result embodies the results assessment, validation or adjustment of the selected direction, priorities selection for further actions.

The teacher's role in RPBL provides the two basic functions fulfilment: firstly, the teachers who taught the students APBL methodology as the certain subject package act as experts; secondly, these teachers act as organizers to help to communicate with external experts from industry and project customers. At the same time they act as members of a students' group working on a project. The teachers' task is to engage into project cooperation the experts, representing the widest range of the most advanced technology with detailed arguments for the benefits, features, prospects of development and experience in implementing the given technology.

When implementing the RPBL methodology an important aspect of the teacher's work is to cultivate and develop in students a sense of confidence in their knowledge and skills in actual real professional work in a particular company while establishing the control system, exceeds by number of indicators the known industrial systems.

6. Results of teacher's functions studies in the evolution of problem-based learning

The above exposed study of the teacher's role has shown that during the teaching methodology evolution from the traditional type of training to PBL and its further modifications as APBL and RPBL the teacher's function are significantly expanded and become more complex and are as following:

1. Source of knowledge in the traditional education, that knowledge sharing through lectures with further fixing in laboratory works.

2. Tutor in classical PBL, who mainly directs and corrects the independent actions of a small students' group in finding, evaluating and using the training resources necessary to solve the problem from the task statement up to its final decision.

3. "Stalker" in APBL, who helps to find at least one solution embodiment for complex problems requiring to apply many disciplines at the same time, to use design and simulation environments, as well as the skills to master the usage examples, provided by software and hardware components' developers. Independently, but under teacher's supervision, discovering other options for stated problem solving the group of students develops not only the knowledge in series of related subjects, but also the use of appropriate control systems design and simulation environments.

4. The expert of the project implementation level and the organizer help the group of students to carry out a real project for the industry, in cooperation with customers and external experts under the RPBL. It is required not only to overpass the known industrial analogues' parameters, but also to lay the possibility for the developed control system further improvement.

7. Conclusions

Changes in the teacher's functions are determined by the steady increase in the control systems' hard- and software development level and thus ever increasing requirements to the knowledge and skills of university graduates. Defining the teacher's functions at each stage of PBL implementation will allow more clearly realizing the PBL methodology in the course of its implementation into the educational process.

Due to the expanded functions of teachers in the educational process, the students' teaching and learning efficiency implies a radical need for teaching staff retraining in advanced teaching methodologies, as well as in the subject area. In addition to self-education, participation in research and practical development activities, another factor contributing to the teaching staff professional development refers to engaging into teaching activities the leading experts from industry, not less important that the teachers' training at enterprises and study of experience with PBL methodology accumulated by the foreign universities.

One of the variances for such European Universities' experience study consists in the participation in TEMPUS VI program projects. An example of such a project is TEMPUS VI "MEDIS" project [10], which frame allows the European universities sharing with six universities from Ukraine, Russia and Kazakhstan their experience in PBL applied to teaching students such subject as the modern industrial control systems design. A maximally broad discussion of this experience will enhance the students' teaching and learning efficiency not only in the control systems design, but also in other fields.

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