PDCA METHODOLOGY OF IT SUBJECTS ADAPTATION: THE CASE OF COMPUTER NETWORKS COURSE

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Abstract: *Dynamic nature of information technology (IT) requires a constant update of IT-related subjects and introduction of acme teaching methods. The paper shows a general methodology of IT course adaptation, applied on Computer Networks course at Faculty of Technical Sciences Čačak. It is based on the well-known PDCA cycle, with the following elements: (Plan) The labor market needs are analyzed, as well as foreign study programs and the adaptation is planned. The e-learning component' fostering is also defined in order to correct the evidenced teaching lacks. (Do)The methodology is going to be implemented in even semester of the school year 2018/2019. (Check) The evaluation is going to be conducted both internally and externally. Results from the exams are going to be analyzed. (Act) Required action is taken by mean of completing materials, peer constructing knowledge and error correcting. It is expected that the methodology will be applicable to other IT subjects.*

Keywords: *computer networks, education, e-learning, PDCA*

1. INTRODUCTION

Computer networks have always been an extremely important part of any computer-related study program. According to the ACM curricula recommendations, Networking is considered as an essential domain and one of IT fundamentals, besides Human-Computer interaction, Programming, Databases, and Web-Systems [1]. Dynamic nature of information technology requires constant innovation of the teaching process. It means two things: 1) update of the body of knowledge in general, including current protocols and devices and trends such as Software Defined Networks in order to stay in line with industry standards and current science and technology achievement and 2) modernization of the teaching methodology, involving more interaction, enhancing the e-learning component and mobile learning.
Faculty of Technical Sciences has a long tradition of teaching information technology and computer science. As Serbian government established the strategy for IT development, meaning a greater number of enrolled students on IT programs, there is an urge for development of teaching strategies able to handle a large number of students, to keep them motivated and to provide them better possibilities for individual learning.
When the curriculum and the syllabus are created, all the accreditation quality requirements were met, including alignment with EU study programs. However, since the accreditation cycle lasts for seven years, new cycle cannot be waited for the courses to be innovated, particularly in the case of IT subjects, which are highly dynamic by its nature.
Serbian Ministry of Education, Science and Technology Development has opened a call "Higher education development" devoted to the enhancement of university and college curricula and teaching methodology. Authors of this paper got a grant for a proposal called "Adaptation and modernization of Computer networks and communications". Elements of the project realization will be presented here.
PDCA is a well-known methodology with its root in the mid-20 century manufacturing organization [2]. It defines continuous improvement through four phases Plan, Development, Control, and Act (figure 1).

Figure 1: PDCA cycle

The four phases are:

- "Plan": Establish the objectives and processes required to deliver the desired results.
- "Do": Allows the plan from the previous step to be enacted. Small changes are usually tested, and data is gathered to see how effective the change is.
- "Check": The data and results gathered from the do phase are evaluated. Data is compared to the expected outcomes to see any similarities and differences. The testing process is also evaluated to see if there were any changes from the original test created during the planning phase.
- "Act": Records from the previous phases help identify issues with the process. These issues may include problems, non-conformities, and opportunities for improvement, inefficiencies and other issues that result in outcomes that are evidently less-than-optimal.

The PDCA is applicable to virtually any process. We have developed a PDCA-based methodology aimed at improvement of Computer networks and communication and potentially applied to other subjects, mainly from the IT field.
The paper is structured as follows: related work is analyzed, then the methodology is developed and the results are presented.

2. RELATED WORK

Ever demanding society expects from schools and universities to keep pace with new trends in information technologies. Consequently, university around the world uses different methodologies in order to improve their curricula in order to provide students with the required knowledge for the future job.
A study conducted by Venkatraman [3] proposed the development of Total Quality Management (TQM) framework that adopts the PDCA cycle for implementing continuous improvements in higher education programs. The proposed TQM framework provides a systematic guideline for effective and efficient implementation of TQM in higher education. However, the author emphasizes that the successful implementation of TQM in higher education requires certain adaption in order to accommodate teaching and learning that forms core functions of higher education.
Teachers from the University of Zaragoza developed a methodology [4] that enhances telecommunication engineering courses. Particularly, they applied the concept of continues improvement to digital electronics subject. They show how the application of a philosophy of quality can help students to achieve so-called "soft skills". Authors used the PDCA cycle as a way of reaching continuous improvement. Results obtained through students' evaluation and level of achievement show that the objectives have been fulfilled. In addition, because of its interdisciplinary character, the authors stated that the method can be applied in other subjects as well.
At the Czestochowa University of Technology, the systematic and generic methodology was used to assure the quality and homogeneity of 28 online courses [5]. In order to successfully plan, describe, create, implement and evaluate these online courses, authors presented a method based on the PDCA cycle. The method was used for managing the e-learning project in three faculties: Mechanics and Machine Building, Environmental Engineering and Computer Sciences. Documents designed in accordance with the PDCA cycle were used to ensure that the courses are of high quality and fulfill the criteria of the University standards. Authors stated that the proposed methodology proved highly efficient.
University Kebangsaan Malaysia has engineering programs that offer students with a good balance between theory and experiments during the four years of study [6]. In order to be competitive with prestigious universities, they conduct continuous quality improvement (CQI) processes. Furthermore, they use self-initiated changes based on the inputs from accreditation panels, industry advisory panels, external assessors and students. Results affirmed that the continuous improvement process carried out at that department level has significantly improved students' learning.

On the other hand authors in [7] propose six sigma improvement strategies in order to determine the critical success factors required in the engineering education curriculum. The main goal was to produce students with skill much needed by industry, and that is adaptability to new conditions and creativity for innovations. For the purpose of the study, the six sigma methodology used DMAIC (Define, Measure, Analyze, Improve and Control) technique, which is a five-step process and the results show that the applied methodology could identify the success factors linked for the development of innovative talent graduates.

The leadership education program was introduced to master students of engineering at the Shibaura Institute of Technology's Graduate School of Engineering and Science with the goal to improve leadership ability of students [8]. After the end of the program, evaluations were made to measure the extent to which students achieved their goals. With evaluation results of clarified learning outcomes, a PDCA cycle was repeated in order to improve the quality of the education program. Authors conclude that the PDCA cycle led to the achievement to produce effective leadership actions of students.

The Lublin University of Technology implements European Qualification Framework outlines concerning strengthening cooperation with industry [9]. They used the PDCA cycle to improve the quality of the established cooperation within the Computer Science course. The paper presents the evaluation of this cooperation with industry made after the project. A survey conducted among industry representatives shows that although companies are interested in conducting internships only 29% are interested in cooperation in the field of curricula development. Authors stressed that the delivered improvements should make mutual cooperation more beneficial for all sides: industry, university, and students.

Authors from the University of Žilina stressed that educational institutions in Central Europe use various models of quality management and that these models only rarely resulted in permanent improvement of the quality of education [10]. Therefore authors used GAP analysis to investigate mutual links between educational facilities, practice, and students. Based on obtained results they have developed a GAP model, which has been adapted for the conditions of university education. The model has been adapted to increase the potential of improvements based on the application of the GAP analysis. It can be concluded that the interest in the improvement of the quality of education is a precondition for the success of such quality management systems and it must be based on the principle of involvement of each individual teacher and university employee in the process of quality improvement.

However, there are some David L. Arnold [11] states that many faculties are not getting the benefits promised by educational institutions concerning continuous improvement. The reasons may lie in disconnections between the continuous improvement model as operationalized in business and industry and the attempt to apply it in an unexamined fashion to educational environments. Author corroborates his statements through several industrial vs. educational institutions a continuous improvement model. In the same work [11] Theodore Marchese gives answers to all Arnold's doubts and stressed that continuous improvement model must be applied to educational environments in order to produce student prepared for challenges of the future work.

3. METHODOLOGY DESIGN

The methodology is formulated through phases of the PDCA, with activities and outputs defined for every phase.
The first phase, **Plan**, includes the following activities and outputs:

- The labor market is analyzed. In order to access as much relevant data, we chose Infostud (web site: www.poslovi.infostud.com) as a relevant indicator of the required task force. Infostud publishes job offerings from thousands of companies, domestic and foreign. According to Alexa ranking, Infostud holds 32nd position in Serbia and it is the top-ranked site of its kind. The findings are categorized and reported.
- Foreign study programs are analyzed in order to look for innovations. Potential innovations are reported. Required additional literature is planned.
- E-learning activities are considered to be enhanced. Although there is a strong e-learning component involved in Computer networks and communications, authors saw a possibility to foster e-learning component and provide continuous communication with students.

The **Do** phase includes the following activities and outputs:

- The program and learning materials are updated. This action is supposed to be taken with care, in order to not disrupt the subject core, or to overload the subject.
- The additional materials are produced.
- The additional literature is purchased.
- E-learning activities are set on the platform. Video-tutorials are produced and put online.

The **Control** phase includes the following activities and outputs:

- The internal evaluation is performed by teachers. The online questionnaire is used.
- The external evaluation is conducted by the Ministry.
- The report is written with the feedback results.

The **Act** phase is devoted to the correction of problems and obstacles founded in the previous phase:

- Rebalancing of the knowledge load.
- Reconsidering the used e-learning elements.

The time the PDCA cycle is timely aligned with the school year dynamic. The subject is held in the even semester. The planning phase is fully conducted in the odd semester. The Do phase is mostly conducted during the semester. The Control phase is conducted at the end of the even semester. The act phase is conducted shortly after. The timing is shown in figure 2.

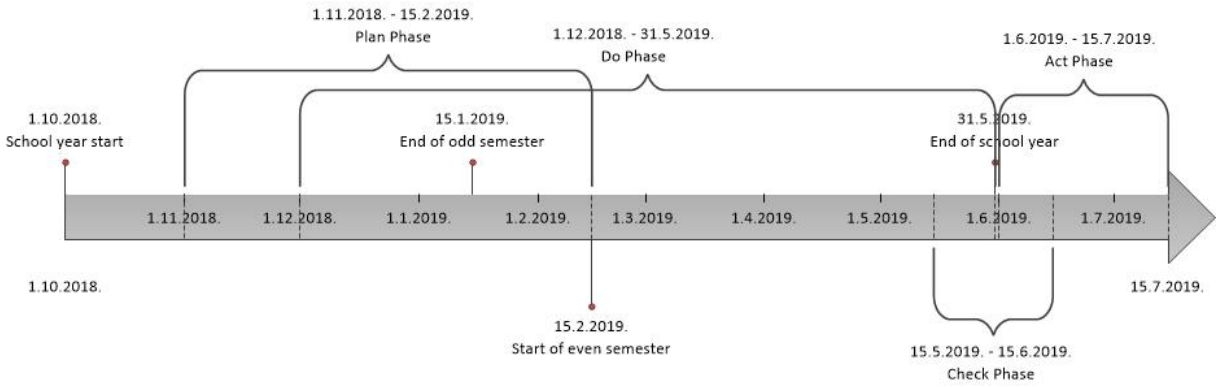

Figure 2: The project timeline

The cycle is supposed to be continued and conducted every school year.

3.3. Adaptation of Computer networks and communication

The mentioned methodology is realized through certain activities. In the following section, we will present specific activities carried out in order to achieve the project results and the relevant gathered data. The planning phase is finished and therefore most of the activities given in details are from that phase. Additionally, the remarks related to the phases in progress and to the forthcoming phases are presented.

Labor market requirements related to computer networking, that we collected browsing over 200 job openings are the following:

- Cloud infrastructure architecture and principles,
- Web-server technologies (Linux, Windows),
- Web security,
- Applicative protocols,
- Cisco and Mikrotik devices,
- QoS mechanisms,
- Microsoft networking technologies.

We analyzed our curricula and found out that many of these elements are covered by other subjects, namely Cloud computing and Computer networks' security. Also, some skills are too narrow, specific and vendor-related to be taught on an academic level. Still, it is concluded that there should be put more accent on network security, no matter that there is a complete subject devoted to this area.

Beside the analysis of the job offerings, we conducted a mini-survey among employers. We asked IT companies to briefly express their needs for general and specific knowledge and skills related to computer networks, which are important for working positions. The response indicated the following elements as required:

- Basic TCP/IP,
- Information security,
- Advanced knowledge of network protocols and services,
- Software-defined networks,
- Cloud computing,
- Active Directory,
- DNS services,

- Virtual Private Networks.

All of the employers put a strong point on the need for student's practical placement and hands-on experience.
Doing a cross-matching of these two sources (calls for positions and employers' survey results) and considering the place of Computer networks and communications in the curricula, we concluded that the following elements are supposed to be added or updated:

- Web-protocols,
- Software Defined Networks,
- Information security.

Additionally, we concluded that the lab-exercises should be enriched and that specific technologies should be introduced in greater extent.
As the "Do" phase is in progress, some elements are already implemented, while others are up to be implemented until the end of the semester.
We also analyzed several modern syllabi from Serbia and from the EU. We reviewed study programs and computer networks syllabi from the following schools:

- The University of Primorska, Faculty of Mathematics, Natural Sciences and Information Technologies,
- The University of Zagreb, Faculty of Organization and Informatics,
- The University of Timisoara, Faculty of Automation and Computers,
- The University of Porto, Faculty of Sciences,
- The University of Belgrade, School of Electrical Engineering,
- The University of Niš, Faculty of Electronic Engineering.

We came to the conclusion that the existing syllabi are in great extent aligned with the analyzed examples and that no need for any specific update is required.
In order to help to retrain the staff, the literature should be updated with new textbooks - general and more specific (related to programming networks and security). The purchasing of the books is mainly finished at the moment this paper is written.
In order to support self-learning, we wrote a book of solved exercises. It is up to be published in the "Do" phase, that is until the end of the semester.
The existing e-learning component comprises of various activities:

- Teaching materials posted online,
- Basic discussion and announcements,
- A few self-evaluated tests,
- Links to external materials.

The Faculty of Technical Sciences is running Moodle platform and this course is set up on the Moodle platform.
We had the idea of improving e-learning component in order to achieve the following goals:

- Enhance communication among the students,
- Provide continual learning,
- Support individual learning.
- Motivate students

In order to achieve these goals, we planned and realized the following e-learning segments:

- Additional moderated forums: question and answers and consultations related to exam questions,
- Additional e-tests covering all covered lessons,
- Video-tutorials (posted to YouTube and linked), covering the exercises,
- Badges are established, as elements of game-based learning.

The "Do" phase is in progress and all of these elements are already partially implemented.
We expect that all of the planned activities will be completed during the "Do" phase, with the remaining phases implemented afterward.
The main output of this first cycle is that students acquire modern knowledge and skills that are pointed towards the future workplaces but also that builds a strong foundation for the forthcoming related subjects and for the next level of study and research.

4. CONCLUSION

It is shown that the PDCA is a simple, but very handy method for management of IT subject adaptation. It is applied for a specific subject, Computer networks and communications, but it can be easily generalized and used for various subjects. Although the phase activities are tailored mostly to fit the IT subjects, it can be more generalized to suit needs for revision and adaptation of virtually any subject.

The Plan phase showed up to be the most important one and rich with various activities, setting the ground for the "Do" phase. There are several activities proposed, but these can be altered in order to meet specific requirements of certain

subjects. However, the core activities, such as analysis of the labor market and enhancing the e-learning component are strongly recommended. However, it showed up that getting feedback from companies was a tedious task and that without personal connections with staff there is a very minor possibilities to get the answers, despite the fact that the survay consisted of very few items.

In future work, we plan to get the results of all the phases and to round-up the methodology effects. We are going to enhance the methodology, making it more formal, then to disseminate it in order to be applied in other subjects and monitor its success.

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