

MASSIVE OPEN ONLINE COURSE "CS50 INTRODUCTION TO COMPUTER SCIENCE" BY HARVARD UNIVERSITY IMPLEMENTATION INTO UKRAINIAN EDUCATIONAL PROCESS

ВНЕДРЕНИЕ МАССОВОГО ОТКРЫТОГО ОНЛАЙН-КУРСА "CS50 INTRODUCTION TO COMPUTER SCIENCE" ГАРВАРДСКОГО УНИВЕРСИТЕТА В ОБРАЗОВАТЕЛЬНЫЙ ПРОЦЕСС В УКРАИНЕ

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Abstract: Nowadays online learning is among the most progressive and most popular educational practices in the world. Both European and United States universities try to implement this way of learning into the educational process. Further development and popularity, the continued blended learning implementation in Ukrainian higher education institutions, requires high-quality new online courses in various fields of knowledge, adaptations and translations of existing courses for the further leading teaching methodologies used in the educational process. Among the best courses in the world for teaching and learning computer science's basics is "CS50 Introduction to Computer Science" by Harvard University and professor David J. Malan. This course was translated in Ukrainian and introduces in the blended format in top-rated Ukrainian higher educational facilities. The comprehensive analysis makes possible further blended learning implementation in the technical educational process in Ukraine.

Keywords: CS50, COMPUTER SCIENCE, BLENDED LEARNING, DIGITAL LITERACY, LIFELONG LEARNING, MASSIVE OPEN ONLINE COURSE, ONLINE-LEARNING, PROGRAMMING.

1. Introduction

In the modern Ukrainian educational process in the higher education facilities, there is an uprising problem to implement cutting edge online-learning technologies to get Ukrainian education to the new level despite the lack of educational professionals, science professionals and restricted access to the world's best learning practices. To overcome these obstacles Ukrainian largest open online courses platform Prometheus (founded in 2014) introduced blended learning technique into top-rated universities' the educational process. Since 2016 over 40 universities in Ukraine have implemented worlds' best online courses into their learning model. The first course that was implemented in blended format was the most popular Harvard's University course "CS50 Introduction to Computer Science" by Prof. David J. Malan.

Modern trends in the world's educational process and the labor market dictate new requirements to the quality of personnel and require the latest technologies to be implemented to the educational process [1]. Thus "CS50 Introduction to Computer Science" implementation is bringing new knowledge and new learning techniques to the Ukrainian students, despite the financial, health lack or other factors that can restrict access to the worlds' best education.

"Computer Science 50 (CS50)" is Harvard University's "introduction to the intellectual enterprises of computer science and the art of programming" for majors and non-majors alike, a one-semester amalgam of courses generally known as CS1 and CS2 [2]. The course was introduced in Harvard in 1989 and taught by David J. Malan since 2007. In 2014 David J. Malan has introduced this course in the form of massive open online course shot in the auditorium with a live audience and installed at edx.org for free access. From 2015 to 2016 the course was translated, voiced over and placed on the Ukrainian massive open online courses' platform Prometheus. Since 2016 this course is streamed from Harvard's auditorium to the Yale University auditorium. The same year "CS50 Introduction to Computer Science" was introduced in four Ukrainian top-rated universities during the blended learning pilot project (National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Ukrainian Catholic University, Lviv Polytechnic National University, Ivan Franko National University of Lviv).

In 2019 the latest version of the course was translated and adapted into Ukrainian by Prometheus platform for the further large-scale introduction in the educational process of Ukrainian higher educational facilities.

2. Preconditions and means for resolving the problem

Computer science in Ukraine is taught with a different methodology. Ukrainian universities have mostly fixed educational plans in which the percent of courses that students can choose by their own is very small. Because of that basic computer science in most universities is taught based on one specific programming language or technology, and further advanced courses usually introduce other languages and techniques of a higher level. This is different to the US approach, where students are faced with many different technologies in one basic course and then can choose which field they want to learn more deeply. Thus "CS50 Introduction to Computer Science" into Ukrainian educational process gives more opportunities to Ukrainian students.

The blended learning format is a formal education program in which a student learns at least in part through online delivery of content and instruction with some element of student control over time, place, path, and/or pace and at least in part at a supervised brick-and-mortar location away from home [1, 3, 4]. In Ukraine, we are at the beginning to introduce courses in the blended format, but after three years only the learning outcome shows that this format is better accepted by students [5] and gives an opportunity to include the best learning practices without financial or other additional efforts.

3. The solution of the examined problem

The first translation and adaptation for "CS50 Introduction to Computer Science" were released by Prometheus platform in 2016. The preparations, translations, editing, sound recording, and mixing were made by volunteers thus had some minor problems regarding content preparation. This project gave Prometheus an opportunity to launch a large-scale campaign to implement blended learning. The scientific team from all four universities regularly (once a week) have worked to create the way for different approaches to combine for course's introduction into the curriculum in 2016/2017. The team proposed changes to the offline teaching workflow and to the supporting documentation. Due to the Ministry of Education and Science of Ukraine requirements, lecturers must produce the documentation package. There are no restrictions to use blended learning but till 2016 there were no official study cases to make it possible.

In the latest course's version that was firstly presented in Harvard and Yale during the autumn semester in 2018, David J. Malan made a lot of changes compared to the 2014 version. First of

all, the course has 10 weeks (in 2014 it was 12 weeks), Malan has introduced a new and very popular programming language Python, also he included lection on databases and have completely changed his approach to different major computer science paradigms explanation (for example, binary system, search types, web technologies and so on).

Now the course's curriculum is:

Week 0. What is Computer Science? Binary. Algorithms. Scratch.

Week 1. C. Command Lines. Data Types.

Week 2. Compiling. Debugging. Memory and arrays. Strings. Encryption. Sorting.

Week 3. Structs. Dynamic Memory Allocation. Pointers. Recursion.

Week 4. Data Structures, Hash Tables. Linked Lists. Tries.

Week 5. Networking. HTTP. HTML. CSS. Java Script.

Week 6. Python.

Week 7. Python. Flask.

Week 8. Databases. SQL.

Week 9. Relaxing Week.

Week 10. Conclusions. [6]

Thus, Prometheus has decided to replace the previous version with a new one and to attract new higher educational facilities to the blended learning implementation project.

The online courses translation, adaptation, and voice-over took almost 5 months to create. The latest course's version includes 18 hours of main lectures, 15 hours of additional videos, 2 hours of walkthrough videos, 6 hours of seminars with the most prominent persons in programming, presentations, notes, problem sets and source code for all the problems described in class.

Lecturers in Ukrainian higher education institutions had a different way to introduce proposed course into the educational process. Firstly, some of them took the course in whole and replaced with it their own courses on basic programming skills or introduction to computer science. This approach was useful for technical students who are not studying to obtain a degree in computer science or in any joint field. For example, such an implementation way was introduced for the first-year bachelor students at the Department of Electronics and at the Department of Manufacture Engineering at National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute" [5]. The results have shown that it was hard for first-year students to understand proposed lectures in full. Thus, lecturers have created stations at the auditorium to split students into several groups and to rotate course. Some students had to watch David Malan's lectures again with a lecturer's explanations due to the proposed material. Other students have successfully finished the lecture and have started working on the problem sets and additional course's materials. Using this approach obtained certificates has become the final evaluation result at the end of the semester.

Another approach was chosen for students who are aimed to obtain a degree in computer science. They have basic knowledge in programming, and they need not to pass all the courses materials. Lecturers had to choose among the course's lectures and additional materials. After that they needed to complete their own teaching program to enlarge it. This approach gave an opportunity to the lecturer to create a new course with parts of "CS50 Introduction to Computer Science" and to include own tasks, tests, and examples. The obtained certificates in this implementation version became the part of the final evaluations result.

In modern blended learning practice, lecturers use different models. The most popular for higher education institutions are a rotational model of various types, a flex model, a la carte model and an enriched virtual model [1, 4].

For proposed online course Ukrainian lecturers have used the rotational model with three interaction types between the lecturer and students. First, the rotational model at the stations, when students move from one part of the audience to another, from the station to the station with a change of activity [4]. For example, the first station provides video lectures viewing, at the second station we have practical use on the chosen equipment, the third station

provides testing, etc. The stations and the order of their use are chosen by the lecturer according to the course tasks or the lecturer, together with the students, to determine the type of work that will be most convenient for all participants in the educational process. One of the successful practices in a rotational model at stations usage is to create own classroom based on the materials of the discipline and to further use such to consolidate the knowledge and repeat the material traversed.

For "CS50 Introduction to Computer Science" the rotation model was used in different educational institutions, but all shared some ways to implement: the most common was viewing course's additional materials or course's main lectures in an auditorium to discuss proposed material. This way was used in all four universities during the pilot project and in 6 universities during the second stage.

The students who have successfully completed the course on the platform, receive personalized certificates from Prometheus. The certificates are generated automatically upon successful completion of graded tasks (Problem Sets) of the course.

The automatic grading system for the course is based upon Open edX xqueue_watcher – open source implementation of a polling XQueue client and grader [7, 8]. Custom developed grading module for xqueue_watcher has a modular structure of 22 Python classes, one for each graded problem in Problem Sets. It uses the underlying Docker-containerized check50 software – an open source tool, that enables black- and white-box testing of students' code, developed by CS50 course team [9]. As long as several Problem Sets need two files to be checked simultaneously, the original Open edX's Advanced problem XBlock was modified in such a way, that it can accept data from more than one input fields representing different files that are being passed to check50.

Graded problems of the latest version of the course are:

Week 1. Hello, Mario (less), Mario (more), Cash, Credit.

Week 2. Caesar, Vigenère.

Week 3. Whodunit, Resize (less), Resize (more), Recover.

Week 4. Speller.

Week 6. Hello (Python), Mario (less) (Python), Mario (more) (Python), Cash (Python), Credit (Python), Caesar (Python), Vigenère (Python), Bleep.

Week 7. Similarities.

Week 8. Finance.

This approach gives an opportunity to have a generation of reliable certificates for successful students, which is not relying on third-party services hosted elsewhere, that are likely to be changed or discontinued in some period. As a result, we can provide an objective grade for each student, on which lecturers who use the course in blended format can base their own grade.

4. Results

As it was mentioned in previous studies [1, 4, 10, 11, 12, 13], blended learning provides an opportunity to overcome the general lack of skilled staff in all areas of knowledge, especially in Ukraine. Specialists in Ukraine do not have free access to most of the world's scientific developments, but due to the openness of massive open online courses and the possibility of using lectures by leading specialists in the field via Prometheus platform in Ukrainian gives an opportunity to overcome the gap in knowledge and provide students with relevant and substantiated material which was fully implemented during "CS50 Introduction to Computer Science" introductory project. Students get access to the best starting a course on programming in the world and professors had an opportunity to change the traditional way to teach with up-to-day technologies and try USA approach in Ukraine.

The online course's "CS50 Introduction to Computer Science" first implementation in 2016 was an unprecedented and successful way to share knowledge in Ukraine which led to the large-scale blended learning implementation, further development of courses' translation and implementation in higher education institutions. The second approach gave an opportunity to use separately or to combine both courses and have an opportunity to show how online

learning can grow and update through the years. In 2019 these gave Prometheus platform to relaunch blended learning implementation and to engage in this process over 20 universities in Ukraine.

The study has shown, the students' progress in the first version of "CS50 Introduction to Computer Science" in the first-year students in comparison with the previous first-year students increased by 13%, and the students' progress in the second-year students was 17%. The number of successful completion certificates of the online course on the platform was 62% of all students who listened to discipline in a blended format [5]. For the second version, we will obtain statistic at the end of the semester (in late June) but now we can argue based on students' statistic both in an auditorium and at the Prometheus platform that these results will increase for at least 5-7%.

5. Conclusions

Massive open online course "CS50 Introduction to Computer Science" was successfully implemented into Ukrainian educational process during 2016-2019. In 2016 the first version of the course launched a large-scale blended learning implementation in Ukraine.

Developed a grading system and modified Open edX modules can be used in further versions of the "CS50 Introduction to Computer Science" and other courses that need a specific approach for grading based on the execution of containerized students' code.

It is planned to carry out the updated version of the course in universities that have already launched it in blended format since 2016 and to continue the implementation in other Ukrainian universities. Provided a technical basis, materials, Ukrainian translation of this course gives the opportunity to introduce it all over Ukraine (at least, at 12-14 national universities) and to create a way for further best world's courses implementation. This will to give Ukrainian students access to the best educational approaches and techniques from all over the world. And will improve the process of getting an education in Ukraine, in general, considering one of the major educational problem in the country – professionals lack.

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