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Alternative Software Solutions for Ensuring the Continuity of the Teaching Process in Emergency Situations

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Abstract: *The pandemic situation in the world caused by the SARS-COV-2 virus and the COVID-19 disease has changed the circumstances in which activities are carried out on a daily basis, including the higher education segment. In the Republic of Serbia, a state of emergency was introduced in a certain period, which resulted in the interruption of regular activities at higher education institutions. Faculties were forced to completely transfer their teaching activities to the online domain in a very short time, which resulted in the appearance of some specific problems. This paper analyzes some of these problems related to the inability to access computer laboratories at faculties. It is shown how these problems can be overcome in home working conditions using the principle of flipped classroom applied to the segment of work with computer laboratories. For the realization of the above, solutions based on the principles of Software-as-a-Service (SaaS), Free and Open Source Software (FOSS) and virtualization were used. The solutions were tested in a real environment during the summer semester of the 2019/2020 school year, an assessment of the success of these solutions is given, as well as some guidelines for their further integration into regular teaching processes.*

Keywords: *higher education; Free and Open Source Software (FOSS); Software-as-a-Service (SaaS); virtualization.*

1. INTRODUCTION

In accordance with the current epidemiological situation in the Republic of Serbia and in the world caused by the appearance of the SARS-COV-2 virus and COVID-19 disease as a direct consequence of exposure to this virus, a state of emergency was declared in the Republic of Serbia on March 15, 2020 [1]. On the same day, as a direct consequence of the mentioned declaration of the state of emergency, a Suspension of teaching in higher education institutions, secondary and primary schools and regular work of preschool education institutions [2] was also declared. The state of emergency in the Republic of Serbia was terminated on May 6, 2020 [3], however, certain epidemiological measures were applied even after the above-mentioned date.

In accordance with the above, during the period from March 15, 2020 to May 30, 2020, or till the end of the summer semester of the 2019/2020 school year, all forms of teaching (lectures and exercises) at higher education institutions for all levels of study (undergraduate, master's and doctoral studies) are performed remotely or in a way that does not require the physical presence of students at the faculties. This practically means that, during the mentioned period, most of the contents within the faculties, which are actively used in the implementation of accredited study programs at higher education institutions, remained inaccessible to both students and teaching staff conducting the teaching process.

Without exception, computer labs also remained inaccessible to students. These laboratories are used in a wide range of teaching activities, since in the digital age there is almost no teaching area that does not involve some use of computers in its implementation. The vast majority of implemented computer laboratories in our education system do not have the possibility to use remote access to resources in these laboratories. The absence of remote access and high representation of computer laboratories in the modern teaching process in higher education raised the question of how to compensate for the lack of computer laboratories in a new situation since most higher education institutions were not adequately prepared for this type of work with students as well as the speed of implementation of this type of teaching process.

The initial predictions were that the lack of use of computer labs would be compensated in a simple way, since the basis is the use of computers, which

are present in almost every home. However, in practice, it has been shown that the process itself hides certain difficulties at various levels that need to be well considered, analyzed and resolved in an adequate way.

It should be noted here that more comprehensive analyzes of the success of universities in the Republic of Serbia in the online regime during the mentioned emergency circumstances are yet to follow, so accordingly most data are not yet available to assess the quality of online teaching [4]. Consequently, only one small aspect will be analyzed in the following lines and it will be shown how the lack of use of computer laboratories is compensated during the performance of certain subjects in basic academic and master studies within the study programs of mining, metallurgy and technological engineering at the Technical Faculty in Bor during the summer semester of 2019/2020 school year.

2. FLIPPED COMPUTER LAB AND ITS CHALLENGES

In recent years, the application of the principle of the flipped classroom has been increasingly used in university education instead of the traditional way of teaching.

In flipped learning model the emphasis is on the student who learns the basics at home using the principles of distance learning while the classroom is reserved for additional questions, explanations, as well as the application of acquired knowledge to solve specific problems [5]. This realization of learning achieves many advantages. Perhaps one of the greatest achievements is that students now show greater activity in the entire teaching process by modifying their behavior from passive to active one [6]. Also, from a technical standpoint, using systems based on this approach can provide more relevant information about wider aspects of learning process, for example various learning styles can be detected using data provided from system logs [7].

The whole epidemiological situation has created such an environment where the use of the elements on which the work of flipped classrooms is based has become necessary in order to maintain the continuity of the teaching process. Without the possibility of using resources within the faculties themselves, work at home has become the basic premise of teaching in all segments of the teaching process in higher education without exceptions. The unavailability of computer laboratories also had to be compensated by a certain type of work at home, so a special working environment was created, which could be conditionally called a kind of flipped computer lab.

When using computer labs in the regular work process, it is assumed that each of the students has his workplace. All workplaces are identical so that the teaching process for all students takes place in equal working conditions. Also, the lecturer has his workplace within the laboratory, which is no different from the student one, so that the content presented by the lecturer on his computer can be adequately represented by the students at their workplaces. All workstations within a computer lab are almost identical in hardware, software, and configuration terms. Also, all workstations are physically in one place, so we essentially have one homogeneous environment that is easy to implement and control.

Contrary to the previous one, we now have a situation that the teaching process is realized using home computers which are owned personally by students or lecturers. These home computers are now taking on the role of workstations used in teaching. Now not all workstations are completely identical in both hardware and software terms, and there can also be enormous differences between them in terms of configuration. Also, these units are geographically dislocated from each other, and network connectivity is realized in different ways. In this case, we have the realization of a very heterogeneous teaching environment with several major challenges that must be overcome in order to achieve the teaching process adequately and under the same conditions for all students.

In order to overcome the set challenges, the first measure was to get known with the hardware infrastructure that will be used in the further teaching process in order to make adequate further decisions regarding the possibility of using appropriate software, configurations and similar. Students were interviewed via email about the important characteristics of the computer that they will use in future work from home, namely: what hardware is their computer based on, the amount of memory the computer has, which operating system it uses and whether it is a 32-bit or 64-bit operating system, network connectivity and optionally year of computer production.

After analysis of the received responses, several conclusions about the equipment which will be used in further teaching process are made:

1) All workstations have newer generation CPUs with virtualization capability,

2) High percentage of workstations have only integrated graphics,

3) All workstations have at least 4 GB of RAM,

4) All workstations use Windows operating system in version 7, 8.1 or 10, except lecturer workstation which is based on Linux,

5) Although mostly 64bit operating systems are represented, there are significant number of 32bit installation.

In accordance with the obtained results, there are several imperatives that must be strictly observed

in the future planning of the teaching process in order to achieve it in equal conditions for all students:

1) All solutions must work on the systems with less RAM (there are significant number of systems with 4 GB RAM with 32bit OS and integrated graphics, so the amount of memory which can be used is approximately about 2-2,5 GB),

2) All solutions can be used equally on Windows and Linux systems (OS independent solutions),

3) All solutions can be used equally on 32bit and 64bit operating systems (platform independent solutions).

Previous observations must be implemented at whole, partial implementation is not allowed in any case, because the ground rule was that every student has equal conditions under which he can master the intended material.

In addition to the above, the software used had to fully comply with all legal norms. A significant fact is that most of the software used within the Faculty is licensed software. Those licenses are valid only for use on computers that are owned by Faculty. Licenses are not transferable and they cannot be used on computers which are in personal ownership, so they cannot be used on student computers at home whatever the purpose is. There are some exceptions, but this is the most common situation, so special attention is taken about the type of licenses, the permitted use of the software, various restrictions and other legal terms related to the distribution, installation and use of the software in accordance with specific conditions of use during the declared state of emergency.

In accordance with all the above, three solutions have been implemented to overcome the described limitations. Two of them were used during the school year 2019/2020, while one solution is intended for introduction into the regular teaching process during the school year 2020/2021.

3. USE OF ONLINE PRODUCTS

First mentioned solution was implemented during the classes of active teaching (computer laboratory exercises) on the course Informatics II in the first year of undergraduate academic studies within the study programs of mining, metallurgical and technological engineering at the Technical faculty in Bor.

One of the areas that are realized within this course is the fundamentals of programming through the introduction to the programming language C. In normal working conditions, to master this area, within the faculty computer laboratories, Microsoft Visual Studio would be used as an IDE that allows student to insert program code and executing it. In extraordinary circumstances, this approach is not the most suitable for home use, especially considering that this course are attending first-year students. In these home conditions, students should be introduced to the method of installation, which can vary from computer to computer, since all classes are conducted as previously mentioned in a heterogeneous environment. Also significant efforts must be made in learning the IDE itself, which can be a complicated process for students who are just gaining experience in this field and get this experience by themselves and in the home condition.

In order to overcome the given problems, the domain of work was transferred to the online world using computers that students have at home. It's already known that using of online solutions offers overcoming many of the traditional constraints that can be found in common higher education systems [8]. Also there is a trend among software vendors to develop Software-as-a-Service (SaaS) solutions latest years which is based on using applications online via web browsers [9]. No installation is required by using software within web browser, so there is a simplicity for providing these solutions to students at any time anywhere where device can be connected to the Internet. According to the previous, the focus was set on finding a C compiler that could be used online via traditional web browsers, so the solution itself will be platform independent and will not require so much use of available resources.

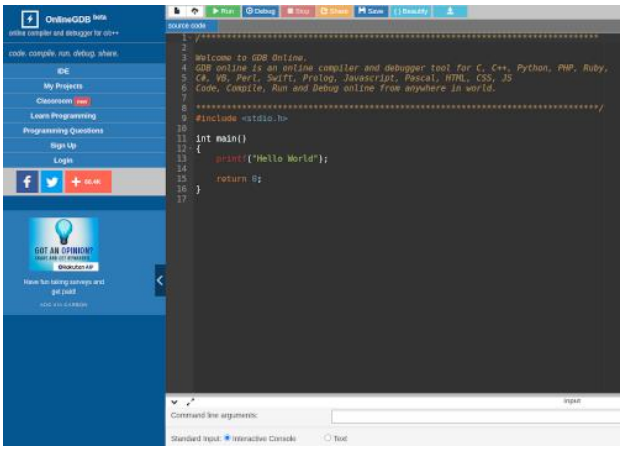

Figure 1. *Layout of OnlineGDB compiler and debugger for C programing language*

OnlineGDB [10] was used within the mentioned course as the product which satisfied presented criteria. This software represents online compiler and debugger for C and C++ programming languages which appearance is shown in Figure 1. As already mentioned, all operations are performed exclusively using a web browser. OnlineGDB has a user-friendly interface which is consisted of simple code editor which is clear, understandable and easy to use. Code editor offers option for downloading a code to local computer or to share code, which is convenient option for using in teaching purposes. Student can run or debug code which is inserted in code editor and output is also shown in the same

window in browser as well as errors and warnings that occurred during the execution of the program.

Within the mentioned online environment, there is a possibility of creating an appropriate classroom in which tasks are assigned to students involved in the classroom. This option was not used on this occasion, as the transition to online working was made approximately one month after the beginning of the summer semester, and there was a problem of harmonizing the use of appropriate data related to students in accordance with the national law on personal data protection. Accordingly, appropriate course assignments and accompanying materials were set within the faculty Moodle platform, and then students solved the assignments using the OnlineGDB platform and sent individual solutions to the course teaching staff using the share or download option. Using one of these two options, appropriate solutions are obtained adequately to the mentioned Moodle platform or are sent to the e-mail address of the lecturer by each student individually.

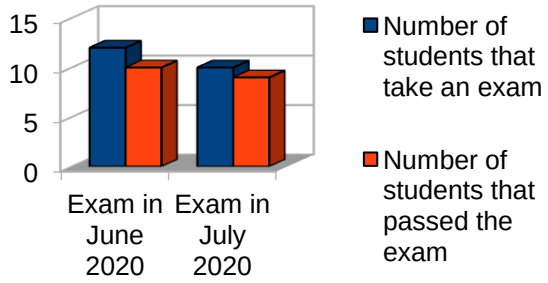

Figure 2. *Results of exams provided in June and July 2020 for course Informatics II*

This online compiler and debugger is used as a pilot software during the summer semester of the 2019/2020 school year. Students have achieved very good results using this software solution. Colloquium realized using OnlineGDB software with maximum score passed over 70 % of candidates. Results of course exams in June and July are presented in Figure 2. Course Informatics II is attended by 36 candidates. As it shown, in first two exam periods, 19 candidates are passed the exam of the 22 registered candidates. Overall score is that over 50 % of attendees are passed exams in the first two exam periods which is very good statistics.

A comparative analysis of the achieved results with previous years is not possible since this is a new curriculum of the mentioned subject. Regardless to mentioned before, analyzing the achieved results of students during summer semester and exam periods, OnlineGDB proved to be a successful software tool for the implementation of planned teaching activities. Accordingly, this solution will come into regular use in the teaching process of course Informatics II during the summer semester of the 2020/2021 school year.

4. FREE AND OPEN SOURCE SOFTWARE (FOSS)

Second mentioned solution was implemented during the classes of active teaching (computer laboratory exercises) on the elective courses Process Measurement Techniques in the fourth year of undergraduate academic studies and Process control in mineral and recycling technologies in the first year of master academic studies within the study programs of mining engineering at the Technical faculty in Bor. These two courses are highly interrelated because the master's degree course is an upgrade to the course being studied in the undergraduate academic studies. Accordingly, both courses are based in software terms on the use of the same platforms.

It was originally intended that students, while attending these two courses, be trained to work in the MATLAB software package and to during courses solve some problems in MATLAB as their personal projects. Unfortunately, due to the mentioned epidemiological situation and the adopted measures, it was necessary to give up working in MATLAB, since MATLAB is a commercial software. MathWorks, vendor of MATLAB software, offers so called student licenses, but it means that every student must buy separate license for his own computer which is inadequate approach from many points of view, economical, technical and similar. So it is concluded that at the beginning of summer semester MATLAB must be replaced with some adequate software by urgent procedure and that software replacement must be from free and open source software (FOSS) domain. If replacement will be from any commercial software domain, same issues will be encountered as in the case of MATLAB software. In short, a free or open source alternative to MATLAB had to be found.

When there are considerations about the use of free and open source software in some domain of education there is generally a fear that free or open source software will have a lack of support, will be more vulnerable and less quality and that at some point will be abandoned in relation to some similar commercial version of the given software [11]. Of course, there are cases like that, but mostly previous considerations can be related at some point to any software in some phase, whether or not it is proprietary (commercial), free or open source software. One of the key characteristic that cannot be provided by proprietary software is free redistribution [12] which is essential characteristic for software use in terms described in this paper and in this particular case which is discussed in this section.

According to the previous our software replacement is defined through some key aspects:

1) No fee may be charged for using the software,

2) Must provide some basic functionalities which are implemented in MATLAB software,

3) Must be well documented,

4) Must be redistributable,

5) If possible, it must enable easy portability of existing MATLAB codes that have already been used in the previous teaching process.

In accordance with the previous requirements best MATLAB alternative for realization of teaching process on the mentioned elective courses is GNU Octave [13]. The layout of the GNU Octave software is shown in Figure 3.

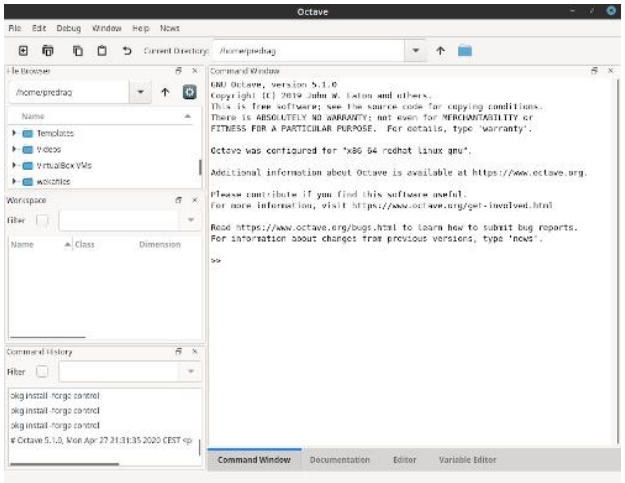

Figure 3. *Layout of GNU Octave software*

GNU Octave is software that provides various numerical computations and it can be used for numerical solution of various problems, linear and nonlinear. Octave has a number of similarities with MATLAB and thanks to these similarities, a high level of portability of the existing MATLAB code can be achieved [14]. GNU Octave is free software and is free redistribute under the terms defined in GNU GPL (General Public License) which means that software is copyrighted and that there are some limitations in distribution of the software [15]. But those limitations are not an obstacle to use software in working with students, as each of the students can without any restrictions and without any registration download the software from the official site, install it on their personal computer and freely use it to master the course.

Table 1. *Achievements of students on undergraduate academic studies*

	Student				
	1	**2**	**3**	**4**	**5**
Assignment	Max. points	Max. points	Max. points	Max. points	Max. points
Grade on exam in June 2020	10	/	10	10	10
Grade on exam in July 2020	/	10	/	/	/

Table 2. *Achievements of students on master academic studies*

	Student			
	1	**2**	**3**	**4**
Assignment	Max. points	Max. points	/	/
Grade on exam in June 2020	10	10	/	/
Grade on exam in July 2020	/	/	8	/

On undergraduate academic studies, GNU Octave software is used for work in the field of statistical processing of measurement results where students worked with common statistical functions. Students on master academic studies are used the mentioned software for work in the field of transfer functions of linear systems, as well as testing of stability of linear systems. On both level of studies, students during the semester had one assignment which are realized in the GNU Octave software. Also, control group on undergraduate academic studies was consisted of five students and on master academic studies control group was consisted of four students. Table 1 represents achievements of students on course within undergraduate academic studies, while Table 2 represents achievements of students on course within master academic studies.

As it shown in Table 1, 100 % achievements of students in the course was realized in basic academic studies in only two exam periods. On master academic studies, as it shown in Table 2, there is 75 % of achievements on exams and 50 % of achievements related to assignment.

A comparative analysis of the achieved results with previous years is not possible since these are new curriculums of the mentioned subjects. Regardless to mentioned before, analyzing the achieved results of students during summer semester and exam periods, GNU Octave proved to be a successful software for the implementation of planned teaching activities. Accordingly, this solution will come into regular use in the teaching process of elective courses Process Measurement Techniques within undergraduate academic studies and Process control in mineral and recycling technologies within master academic studies from 2020/2021 school year.

There are some estimations that the inclusion of the GNU Octave into the teaching process will bring annual savings to the Faculty of several thousand euros.

5. VIRTUAL MACHINE - VM

Previously analyzed solutions are implemented during summer semester 2019/2020 school year

in aim of ensuring the continuity of the teaching process in the current conditions caused by the epidemiological situation in the Republic of Serbia. That was a pilot solution which will be used regularly within Technical faculty in Bor in summer semester of 2020/2021 school year.

The current situation has taught employees in higher education to look at the bigger picture at the moment and to expect similar challenges in the next school year, and it is necessary to adequately prepare for these challenges. In that sense, the solution that will be presented in the following lines has not been implemented yet, but it is expected to be implemented soon, at least in the form of a pilot project.

In this situation when students practice learning from home using their personal computers and other personal resources, two great needs must be met. On the one hand, it must be possible to master the course through achieving certain teaching goals. On the other hand, using recommended software, configurations and similar technical things could not produce lack of the protection, stability, availability and security of each individual student's personal computer [16]. The above, the creation of a secure and functional environment for working on students' personal computers can be achieved by using the basic principles of virtualization. Virtualization techniques have significantly made progress in recent years, so today, using modern techniques and principles of virtualization, in a simple way various forms of training can be effectively achieved [17]. Also, virtualization brings an optimized approach in overcoming the already mentioned problems related to distance learning while reducing the whole range of side effects that can occur, such as maintenance costs [18].

A so-called virtual machine is created for a specific course or group of courses. Virtual machine is consisted exclusively from free or open source software to avoid potential distribution and licensing problems. Then, that virtual machine will be uploaded on some server on the Internet so that students can easily download it to their computer. After the downloading student start virtual machine using specialized software (for example Oracle VM VirtualBox Manager which are free to use) on his own computer. The student does not perform any installation and no adjustment of the virtual machine, all this is done for the student by the faculty staff in advance. All work is performed by the student in an isolated virtual machine environment so that the potential risk to the student's personal computer is reduced to a minimum.

For example, for particular case of using GNU Octave software described in previous chapter virtual machine will be based on some Linux distribution (for example Fedora 32). Within installed Linux will be installed GNU Octave. After installation of GNU Octave all necessary packages will be downloaded and loaded into the software. Operating system and whole software will be preconfigured so student have no obligations to set up environment, software and similar. Also within the virtual machine will be placed various examples, tutorials, manuals and other relevant documents so that student does not have to search the internet and download necessary materials.

The advantages of this approach are numerous, some of those have already been pointed out in previous lines. However, we must be consistent and mention two negative aspects of this approach, the need for a slightly larger amount of RAM on the computer running the virtual machine, as well as the need for a slightly larger free capacity on HDD or SSD for virtual machine location.

6. CONCLUSION

Most higher education institutions in Serbia have implemented online learning systems that they use in parallel with traditional forms of teaching. The Moodle platform is mostly used, but many other platforms are also used, such as Google Classroom and the like. Therefore, the system of higher education in Serbia could very quickly adapt to new circumstances that required that the entire teaching process in less than two weeks must be fully transferred to the online domain and that all teaching activities must be held online.

However, as far as computer labs are concerned, the situation is completely different. Faculties, in accordance with the standards and instructions related to the appropriate national accreditation of higher education institutions and related study programs, generally have very well-equipped computer laboratories that are functional and offer a wide range of possibilities. The mentioned computer laboratories in most cases do not have the possibility of remote access and remote work with their resources. Also, in most cases have not been considered and there are no alternative software solutions that would be applicable in terms of use in online teaching.

The current situation has led the higher education community to think about this issue and in the previous lines are presented some applicable solutions that have been tested in the actual teaching at the Technical Faculty in Bor within the summer semester of the school year 2019/2020.

The first solution was based on the use of online software in teaching based on the concept of software as a service (SaaS). The mentioned solution provided simplicity and efficiency in performing the teaching process in the appropriate course, both on the part of the lecturers and the students. Extremely good results were achieved in the implementation of this solution, so that the use

value of the mentioned solution was confirmed, which created the conditions for the introduction of these principles in the regular teaching framework in the future semesters.

When the presented solution is compared with the previous practice, the key advantages are reflected in the flexibility that the mentioned solution brings in various aspects of work. Since the entire execution of tasks in the mentioned environment requires only Internet access and a web browser, this solution is completely platform-independent, which allows execution on almost all systems, so no additional requirements need to be set related to necessary equipment. Since use is completely free, there are no additional costs that could further financially burden the faculty. Also, the interface itself is clear and easy and no additional effort is needed to explain the basic principles of working with the environment. On the other hand, two potential usage problems have been identified. If the mentioned environment would be used with its expanded possibilities (classroom), since certain data on students outside the domain of the faculty are entered, additional efforts would have to be made in harmonizing this way of use with the existing legal regulations. Also, within the environment, various advertising messages are broadcast over which the faculty has no influence, so the faculty should clearly distance itself from any marketing activities of this type and make it clear that these advertising messages do not in any sense reflect any faculty policy or opinion.

The second presented solution was based on overcoming the problems posed by the use of commercial software and the limitations of the licenses under which such software is distributed. Overcoming the identified problems was based on finding free and open source software (FOSS) alternatives to previously used proprietary software. The mentioned solution was tested in the conditions of teaching in narrowly professional subjects at different levels of education within one study program. In this case, too, the alternative solution was confirmed through extremely good results in the implementation of teaching activities during one semester, which created the conditions for the solution to be applied in the future as a permanent solution in the teaching of appropriate courses.

In this case, the dominant advantage is expressed through the fact that these types of software can be used in the teaching process free of charge and that in most cases they can be adequately distributed among students and teaching staff, which is generally not the case with proprietary software. The faculty itself does not have to provide additional efforts and resources related to software distribution of this kind, since the software is in almost all cases simply downloaded from an Internet site defined by the vendor. Some vendors require registration in order to enable proper downloads which raise personal data collection issue. Although, mostly, students register individually, it would be good practice for the faculty to at least warn students about potential risks of giving personal data and that the faculty is in no way involved in the collection and processing of those personal data. In some cases, this situation can be avoided if the faculty takes responsibility for the software distribution itself, but this can, on the other hand, create additional costs for the faculty in terms of providing additional resources.

As can be seen from the previous, both solutions meet a number of criteria that had to be met in the special conditions of teaching during the summer semester of the school year 2019/2020. This proves that teaching in higher education study programs can be performed equally efficiently in the absence of the use of commercial software while maintaining a high level of teaching and good output results.

Especially great success is expected from the introduction of the principle of virtualization in the implementation of computer laboratories. This concept will be tested during the school year 2020/2021 in real teaching conditions and it is expected after the pilot program that the mentioned concept will be introduced in regular classes during the school year 2021/2022. By introducing the concept of virtualization, the principle will be realized that regardless of the place where the intended tasks are performed (home conditions, computer laboratory or some other location), the student always has an identical environment for work in software and configuration terms. Also, the possibility of unforeseen circumstances (errors, impact on computer operation, etc.) will be minimized.

What must be especially emphasized is the fact that by using such solutions, faculties achieve many benefits not only in terms of maintaining and improving the quality of teaching, but also in minimizing the resources needed for their implementation, as well as in economic terms.

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