Transition from the classroom to online educational environment: First impressions

Petre Lameski, Vladislav Bidikov, Kiril Kjiroski, Boro Jakimovski,
Eftim Zdravevski, Ivan Chorbev and Vladimir Trajkovik
Ss. Cyril and Methodius University in Skopje
Faculty of Computer Science and Engineering
Skopje, North Macedonia
{lameski, vladislav.bidikov, kiril.kjiroski, boro.jakimovski, eftim, ivan.chorbev, trvlado}@finki.ukim.mk

***Abstract*—With the world pandemic caused by the COVID-19 virus, the lectures at the Faculty of Computer Science and Engineering (FCSE), at the Ss. Cyril and Methodius University in Skopje, Republic of North Macedonia, were fully transferred online within the first week of the start of the imposed movement and public gathering limitations by the Government of North Macedonia. After two weeks of the start of the classes, we performed a survey for both students and faculty teaching staff to gather the initial sentiment for the online classes and to identify opinions, suggestions for best practices and possible obstacles. In this paper, we present the technological solutions used to give the lectures and the results of the initial surveys.**

***Index Terms*—distance learning, moodle, e-learning, online education**

I. Introduction

Due to the COVID-19 pandemic, the education process in North Macedonia has been rapidly transferred from the blackboard and smart classrooms to the online tools. Within the first month of the proclamation of the emergency state from the government, almost all educational institutions have transferred to the available online conferencing platforms such as Zoom [1], Moodle [2] and Microsoft Teams [3].

Given the need for rapid transfer to these technologies, the process's full digitization was done almost without an in-depth analysis of the technology acceptance. Some of the schools and faculties opted to stop the classes for the semester. They decided not to continue online due to the lack of technology acceptance by their teachers and students. The technology acceptance of online learning and education in general, has been discussed many times in the literature [4]. The reported survey suggests that faculties are more eager to accept online education if they perceive the usefulness of such technologies, regardless of the ease of use. The study shows that usefulness seems to be a major indicator of the acceptance of online learning. Authors in [5], find that teachers that teach more traditional courses are less likely to easily migrate to online learning and provide online courses and curricula. Be that as it may, since 2011, many universities have offered undergraduate, professional, and masters online degrees. The quality of experience and quality of service measurements are significant for online classes, primarily when classes are intended for students [6]. Among the first companies that offered fully online courses and degrees with the possibility of certification were Udacity [7] and Coursera [8], which quickly became trendy tools for online learning. The number of faculties that offer online educational opportunities increases every day. The COVID-19 crisis further sped up the process of improving and increasing the volume of online education.

The technical faculties, especially FCSE, were at an advantage because online classes and conference meetings are not a new thing in the ICT sector. The Faculty has already participated in several projects for online education such as The ViCES Tempus project [9], which included Teleconferencing equipment and classroom in which online lectures were organized since 2011. The initial experiences were very optimistic and the quality of experience for students was on a very high level [10]. Furthermore, the courses in the Faculty were already hosted on the Moodle platform. The same platform was also used for organizing tests and exams within the Faculty laboratories and sometimes online.

FCSE at the Ss. Cyril and Methodius University in Skopje, the largest technological Faculty in North Macedonia, started the online lectures within one week from the government proclamation. In this paper, we present the technologies used by the Faculty staff and students and the initial student and professor feedback and satisfaction from the online lectures.

In the following sections, we describe the used technologies and present selected results of the performed survey for both students and faculty teaching staff.

II. Technology stack

A. Hardware and software resources

*F*aculty of computer sciences and engineering has been a crucial part of the Macedonia e-Education Project. In the course of this project, a Container Data Center was installed on the Faculty premises. Employees at the Faculty Computer Center (FCC) took an integral part in the installation of all computing, storage and networking resources. That enabled us to plan, test and implement various virtualization and cloud systems. As a result of this effort, many national platforms are today hosted at Faculty premises, and we strive to test and improve on our previous experiences. Taking a portion of the installed equipment, FCC implemented a highly available and fault-tolerant virtualized environment for implementing the e-Education platforms. This platform's goal is to enable teachers

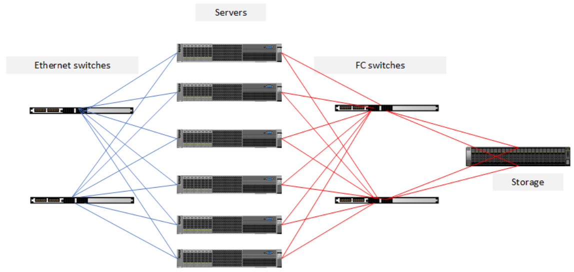

Fig. 1. Hardware connections for used equipment.

and students to take active participation in our efforts to provide an uninterrupted continuation of the education process in these moments of social distancing. Following hardware resources were (either partially or fully) used in this effort:

- six Huawei RH5885H V3 servers
- one Huawei OceanStor 5500 V3 FC storage system with redundant controllers
- two SNS2248 Fiber Channel switches
- two Huawei Cloud Engine 6851 10 Gbit ethernet switches in a stacked configuration

*F*ig. 1 represents hardware interconnections. *A*ll of the servers have the following configuration:

- Two Intel(R) Xeon(R) CPU E7-8880 v3 @ 2.30GHz
- 256 GB DDR3 RAM @ 2.13 GHz
- dual 2600 Series 16Gb Fiber Channel HBA
- dual Intel 82599EB 10 Gbit network adapter

Storage and servers are interconnected using SNS2248 FC switches, where each server and storage controller are connected to each of the switches for redundancy. Additionally, servers are connected to the rest of the network using stacked CE6851 switches, also in a redundant configuration. Thus, there is no single point of failure, and FCC put in place various monitoring mechanisms to enable prompt and accurate reaction in case of hardware failures.

For server virtualization, we used VMware ESXi, version 6.5.0, and vCenter Server Standard, version 6.5.0, for the centralized management and operation. VMware cluster is working in High Availability mode, with 10% of CPU and 10% of memory dedicated to maintaining this HA environment. Two 10 Gbit ethernet adapters per server are used for networking, both connected to the same virtual switch, thus providing redundant and load balancing network connection. Network is implemented through VMkernel ports, using two such ports. One for management and virtual machine connection purposes, and the other for vMotion.

Storage is organized in the following fashion:

- Performance Tier, comprising of ten 600 GB 15k rpm SAS HDD disks, organized in RAID 5
- High-Performance Tier, comprising of eight 900 GB eMLC SSD disks, organized in RAID 5
- Total usable capacity of 8 TB

Storage has redundant FC controllers, each equipped with two 16 Gbit FC adapters. Each of the controllers is connected to both FC switches, thus providing redundant storage network connections. This configuration also enables load balancing between servers and storage, utilizing Round Robin for multipath connections. This contributes to faster and more reliable communication with the storage. All virtual machines and corresponding files, such as disks and swap files reside on the storage, and can be migrated to another storage if necessary.

Between storage, servers and FC switches, there is no single point of failure, and monitoring has been implemented to alarm FCC staff in case of any hardware or software outage. FCC is monitoring computing, storage and networking elements using the following technologies:

- Monitoring of networking elements using SNMP monitoring and reporting tool LibreNMS
- Monitoring of hypervisors, virtual machines and storages using Veeam One Monitor
- Monitoring of virtual machines and services using Zabbix

The cluster network connectivity to the external environment was based on implementing VLANs through Virtual Machine Port Groups and using two 10 Gbit network interfaces as aggregated 20 Gbit network connectivity on virtual switches. This architecture enables implementing more than three hundred virtual machine network interfaces on more than fifty different VLANs using just these two physical interfaces. Three of these VLANs were used in our platform's implementation, as will be described in detail later.

In order to provide a better end-user experience for the users, additional work was done on the topic of network connectivity. FCSE is already well connected to the general internet based on two full Internet up-links as following:

- 1 Gbit upstream via GEANT project provided via the University network
- 500 Mbit upstream via a commercial ISP provided in cooperation with the Ministry of Education

Based on our knowledge of the way Internet service providers are connected between them and based on the Faculty project for national network connectivity and research IXP.mk we established the need to have appropriate network capacity for our future endeavors. It was decided to use the IXP.mk platform to allow for direct connections between the FCSE and several Macedonian Internet operators. We based our work on establishing a separate Autonomous number (AS) for the FCSE network and its' connection to the University network and commercial operators via a dedicated router based on the Bird routing software [1]. In order to be able to scale the system and handle this expected additional load expected, it was decided to switch from a bare-metal hardware machine to a virtual machine running on the same infrastructure. This would make the router also highly available and eliminate the single point of failure which a bare metal machine was presenting.

On the software side, we already had both systems for courses and exams running on the Moodle LMS, so we only

[1]https://bird.network.cz/

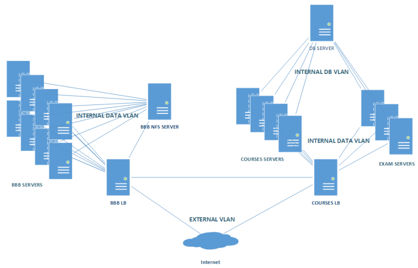

Fig. 2. Logical interpretation of server platform interconnections.

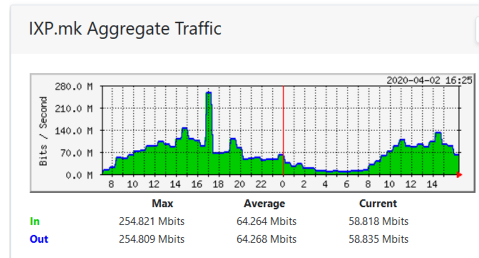

Fig. 3. Traffic over IXP.mk platform on 2020-04-02.

needed to add the part of the system, which will allow easy web conferencing for the teachers and students. Based on our previous experience, we were quite sure that we have the perfect platform for this based on the Big Blue Button[2] open source web conferencing system. The Big Blue Button web conferencing system was the perfect match since it already has all the required tools to aid in the teaching process. As expected, based on our size and number of students, we also saw the need to scale this component.

Scaling for the LMS part of the systems was generally an easier task. We only needed to be sure that we use the appropriate number of end nodes and use the already established Load Balancer server we have for most of our Faculty services. The scaling of the web conferencing component was a bit more challenging. It was resolved by implementing an open-source project which we had to customize based on our needs heavily.

At the end this is the final platform setup which we use now:

- Course learning platform using three front end nodes
- Course exam platform using four front end nodes
- Database server for course learning and course exam platforms
- Load balancer virtual machine serving both course learning and exam clusters to end-users
- Big Blue Button web conference platform comprising eight web conference front end nodes, one NFS storage and special BBB load balancing machine.

Previously mentioned VLANs are used for interconnection in the following way:

- External VLAN for load balancers serving content from course and web conference platforms to all users
- Internal VLAN for exchanging data between load balancers and application servers
- Another internal VLAN for database access between the database server and application servers

Logic interconnections and appropriate VLANs between web conference servers, recorded video server, course servers, exam servers, database server and load balance servers are depicted on Fig. 2. All lines drawn between the servers symbolize data connections between them and do not represent any existing physical logical connections.

[2]https://bigbluebutton.org/

To fully utilise the internet capacity and provide better end-user experience for the web-conference platform, we decided that the Course learning and exam systems will use the University connectivity and the BBB platform will use the commercial and IXP.mk connectivity. This would allow audio and video traffic to travel the shortest path thanks to the IXP.mk platform, thus providing better quality, and in the long run, it will offload connectivity needs for the service providers where the teachers and students will connect.

Our effort on using the IXP.mk platform was quite well accepted with all Service Providers in Macedonia. In a matter of several days, we got connected with: Macedonian Telekom, Telekabel, Telesmart, Interspace, all combined with the presence of the University network. Also, the IXP.mk platform allowed for most of the traffic to flow over this high-capacity platform of loading this traffic from Commercial operators' internet links. This benefit is clearly shown in the following Fig.3, where total traffic is shown flowing on 2020-04-02, where we saw the maximum amount of traffic which we observed.

The presented platform gave the expected results, and we never saw any possible resource bottleneck based on the network's capacity or the available virtual resources.

The biggest challenge was providing a secure way to execute the partial exams that were coming and required that we use the exam platform in a form where students access it from their home computers. For this task, the only viable solution was already known to us as part of the Moodle LMS, but we had to test the system's sustainability and stability. Moodle already has support for a particular component known as Safe Exam Browser [3], which allows for more precise control of exams done with the Moodle Quiz activity. We just needed to test how this component will work on the clustered exam system and how much more resources it will use since the Safe Exam Browser required an additional access module to be active on the Moodle LMS. After the initial testing, we saw that the system was with good quality and it was presented to the teaching staff in order to be used if required for exams.

The current development of Safe Exam Browser is still not completely in line with both supported platforms Windows and Mac OS X. However, based on its more frequent usage in this time of global pandemic, we see that development is gaining

[3]https://safeexambrowser.org/

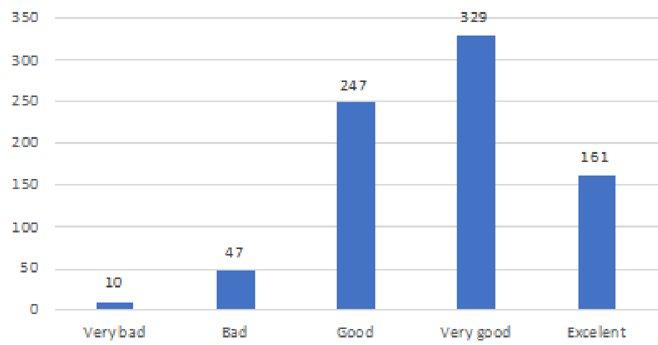

Fig. 4. General satisfaction of online education by Students

momentum, which means that we will probably have the technical capability to further enhance its usage into the FCSE LMS systems. The faculty computer center already committed some valuable feedback to both Big Blue Button and Safe exam browser Moodle LMS integration projects based on their own experience in using them in a very clustered environment.

III. Evaluation protocol

The Faculty of Computer Science and Engineering has over 4000 active students and over 70 teaching staff that use the online system. For this purpose, we used our online system (Moodle) for surveying both the teaching staff and the students. The survey was anonymous. The students and teachers were asked a different set of questions, some of which included performance measurements and their home computer setup details. The results of the survey are presented and discussed in Section IV.

IV. Results and Discussion

Much analysis can be performed from the filled-in surveys by the students and teachers. For the purpose of this publication, we have decided to use only the initial satisfaction from online lectures and compare it to the observed satisfaction from traditional lectures performed in classrooms. We focused our initial analysis on two questions: “How do you evaluate the general experience with the online lectures?”, and “Compare the traditional lectures with the online lectures?”. For the first question, the students had to choose between 5 options from best to worst: Excellent, Very good, Good, Bad, Very bad. For the second question, the students chose between 5 options too: Online much better, Online better, Equally good, Traditional better, Traditional much better.

On Fig 4 we can see the results of the general satisfaction from online lectures by students. We can observe that large majority of students are very satisfied with online classes. Only 10 students evaluated the online classes as very bad which scales to less than 2% of the students. More interesting observation can be made by seeing the results of Fig 5. It can be observed that the satisfaction from online classes generally grows as the students are more experienced with First and Second-year students being less satisfied than Third and Fourth-year students.

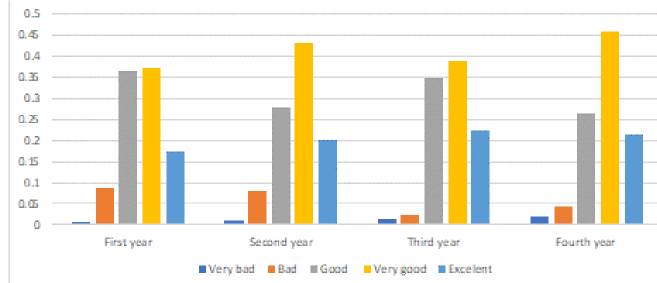

Fig. 5. General satisfaction of online education by Students

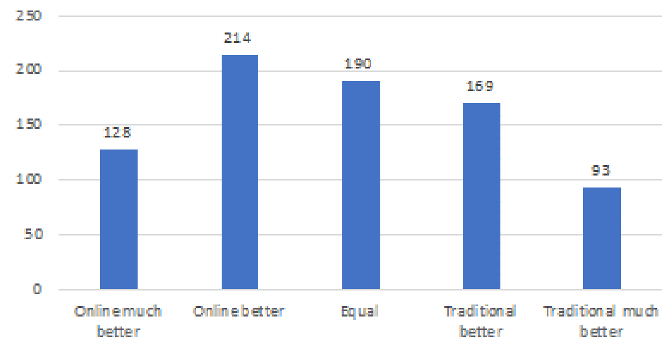

Fig. 6. General comparison of Online VS Traditional classes

A similar observation can be made when we compare the student satisfaction from online and offline classes. As can be observed in 6, the majority of the students evaluate the online classes to be equal or better than traditional offline classes. Furthermore, when we compare the distribution of answers per year (by normalizing for the different number of responses per year), we can see that similar to the observation about the general satisfaction, higher year students tend to like online education more than the lower year students. In general, the majority of the students from each year, prefer online education. However, the number of those who think that traditional is better or much better lowers down as the study year increases. When asked why they prefer online education in the survey, students explained that they like online classes more because they do not need to commute to the faculty premises and they can follow the classes comfortably from

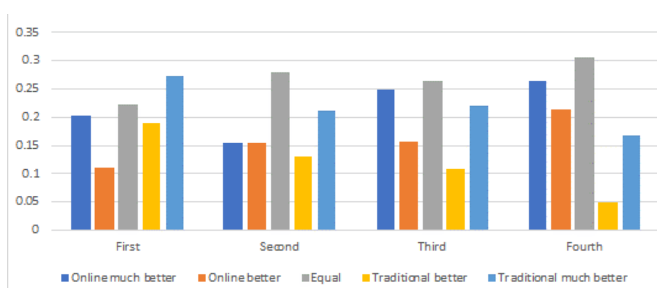

Fig. 7. Normalized per year distribution for comparison of Online VS Traditional classes

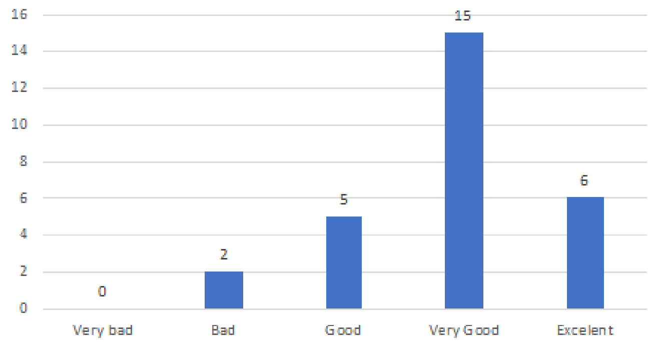

Fig. 8. General satisfaction of teachers from online classes

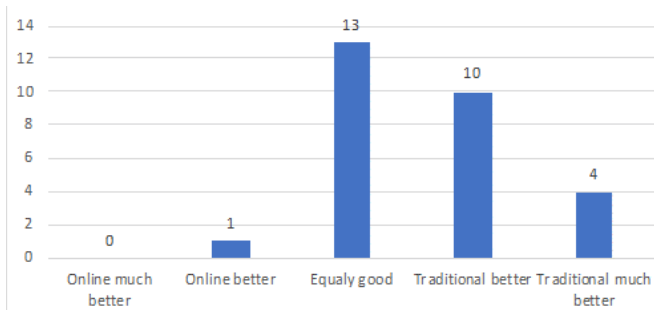

Fig. 9. Comparison of online VS traditional classes satisfaction by teachers

their homes. Another reason is that most of the classes are recorded and they can watch them later when they feel like it. On the other hand, students complain to lack of classroom context, lack of interaction and bigger dissatisfaction if the online classes are live and not recorded.

We did a similar survey for the teachers and the results were significantly different from the results from the students. For example, if we observe the general satisfaction from the online lectures by the teachers in Fig 8, we can see that the teachers are similarly satisfied with the online lectures. However, if we see Fig 7, we can observe that by a large margin, teachers believe that traditional classes are equal or better than online classes. Based on the followup answers, the main reason for the lower satisfaction from online classes is the lack of live interaction on the classes and the classroom atmosphere, which cannot be emulated by the online classes environments and tools. In a live classroom environment, teachers can get both audio and visual feedback from the students and estimate the degree of understanding. This is lacking in our online classes, where students mostly chose to connect only for listening and almost never turned on their camera.

V. Conclusion

Thanks to the rapid response of the teaching, administrative and IT staff FCSE has successfully implemented online learning and fully restarted the classes on 2020-03-17, with several classes being experimentally held in the previous period. This was done only seven days after the faculty premises were closed and the on-premises classes were banned. Based on the initial survey, both students and teachers are generally satisfied with the online classes. However, there seems to be a different initial perception of the online courses from teachers and students. Furthermore, older students seem to prefer online lectures rather than traditional ones, while most teachers prefer traditional lectures or consider them the same. Additional surveys are planned after the end of the semester. Additional research is planned after the results from the exams to evaluate online education further and compare it with the traditional one. Based on the initial survey, we can conclude that FCSE has successfully migrated towards online education, especially for regular classes and auditory exercises. There are still many challenges to be overcome, such as limitations of students' equipment, organizing exams, and laboratory exercises, some of which are very difficult to implement in an online environment.

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