

Impact of hybrid teaching methodology during COVID-19 pandemic on Operating systems course

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Abstract—Since 2019 the COVID-19 pandemic has caused huge changes in our lives. The government’s health policies restricted everyday life, especially in schools. In the school year 2021/2022 we had to teach smaller groups face-to-face and later in the semester switch to distance learning. This article focuses on the Operating systems course teaching techniques used during the school year 2021/2022. Operating systems are one of the fundamentals needed for the development of complex UAV systems.

Keywords—e-learning, operating systems, UAV, COVID-19

I. INTRODUCTION

UAVs (Unmanned aerial vehicles) have various usages nowadays. The development of UAVs is a complex process regarding physics, electronics, but also operating systems. Knowledge of operating systems is essential, especially for more complex UAVs, that require access to operating system functions. This article focuses on Operating systems course teaching techniques which have impact on the future of UAV development [6].

Since the start of the breakout of COVID-19, the government’s measures have made it impossible to teach students face-to-face like before the pandemic. During the school year 2020/2021 in Slovakia, schools had to switch to distant teaching. During the school year 2021/2022, the government’s measures were not as strict as in the previous year. We were able to retain face-to-face teaching, however, each group was split into two subgroups that alternated each week on lessons. This was done to minimize the chance of COVID-19 transmission. In this article, we will discuss methods that we used during hybrid teaching and measure results based on answers from the survey. Our groups for operating systems usually consist of 24-27 students.

The structure of this article is as follows:

- Section 2 is devoted to related work regarding operating systems and teaching during the COVID-19 pandemic,
- Section 3 contains information and content of operating systems subject,
- Section 4 presents changes made in operating systems subject to dealing with health policies,
- Section 5 contains results from the student’s survey,
- Section 6 presents results collected from the operating systems course in Moodle,

- Section 7 is devoted to discussing the results from the student’s survey and results from Moodle,
- Section 8 summarizes findings and efficiency of teaching during the school year 2021/2022.

II. RELATED WORK

In recent years (2017 - today) there has been an ongoing process of improving the quality of teaching the Operating systems subject. As a part of this process, students are asked to fill in an online survey. Results from this survey are then analyzed and published in a paper showcasing the results of the process. In this section, we summarize the results of this process up until now.

In 2017, project and team-based teaching were introduced [3]. This means that the teaching was based on the interconnection of practice and theory and students were working on the assignments in pairs (Copymaster) or teams of three (IPC). This brought an increase of students successfully completing the operating systems course by 28.61%.

In 2018, project and team-based learning were examined further [4]. The results from this year’s questionnaire affirmed the previous observations.

In 2019, [1] the trends from previous surveys were visualized and analyzed. They showed that students valued project-oriented teaching, understandability, and variability of study materials and a fixed range of topics where principles of study are directly practically exercised.

In 2020, [5] we once again examined the trends from previous surveys and correlated them with student learning outcomes. A few interesting points were discovered such as the fact that the number of complaints about assignments does not correlate with student pass rate, there is a correlation between student pass rate and subject recommendation and team projects are popular even with uneven contribution proportions between the team members. Based on the unpopularity of the Scripting assignment that this survey showed, we decided to exclude it from the list of assignments for the next year.

In 2021, [8] we examined existing platforms that offer an interactive environment for programming courses and discovered that there is no platform that would offer all of our criteria (it is free to use, it has a code editor, offers code testing, control questions and work in bash-like terminal). We wanted

to use a tool like this to help us overcome the challenges of the COVID-19 pandemic. Because we did not find such a solution, we decided to develop and test our own which we described in the article. We then surveyed student opinions. We found out that students were mostly satisfied with this tool. They only had a slight issue with user-friendliness of the user interface.

Complex UAVs require access to the operating system functions. For developers of UAVs it is necessary to understand the fundamentals of operating systems. Zheng et al. [10] analyzed real-time operating systems from the network perspective. They focused on various versions of FreeRTOS, one of the popular operating system kernel for embedded devices. Sobhy et al. [7] analyzed the possible usage of cloud operating systems for UAVs. Tisdale et al. [9] described the software architecture of the developed Berkeley UAV platform. They mentioned basic operating system algorithms, like round-robin or FIFO, that are part of the curriculum in the Operating systems subject. Barton et al. [2] analyzed security of popular UAVs systems.

III. OPERATING SYSTEMS

The Operating systems course is taught at the Technical University of Košice to students studying computer science and similar technical fields in the winter semester of their second year of bachelor's study. The subject traditionally consists of one three-hour long lecture per week and one two-hour long seminar per week. The lectures focus on theory and principles of operating systems such as process scheduling, memory management, and similar topics while seminars focus on operating systems programming.

In the past years, there were dramatic changes in the structure of seminars, as described in section II. At the time of the survey this article is concerned with, there were two assignments students had to work on.

The first and easier one of the two was the Copymaster assignment where students had to implement a program based on a specification that would, in its basic form, copy the contents of one file into another one. This easy task is complicated by up to 14 command line arguments that influence the run time of the program such as deleting the original file after copying, specifying file access rights, and so on. Some command line arguments can be combined while some can't. The purpose of this assignment is for students to apply the knowledge about file system which they learned in the first half of the operating systems seminar.

The second assignment called IPC (Inter Process Communication) is concerned with problems that arise from inter-process communication, mainly synchronization of communication. This assignment consists of modules that communicate with each other. Some modules are already implemented and offered to students in a form of a binary file, other have to be implemented by students based on incomplete specifications. Part of the assignment is first to finish the specification and implement the system.

Besides assignments, students have other curricular activities such as:

- Pretests are online tests students may complete as part of their preparation for a seminar. While filling them, students can use any external tool, mainly study material Sofia and Linux manual pages. If students commit the wrong answer, they can correct themselves and lose points only partially. If they gain more than 70% of available points from a single pretest, they are graded.
- Homeworks are sets of tasks that students can complete after a seminar lesson. They mostly consist of practical tasks of which output is source code and output of the compiled program, output from commands but also include asks where students have to find answers to questions or properly define concepts.
- Test examinations are performed in the middle and at the end of the curriculum. The first examination covers the first part of the curriculum concerned with file system programming (same as the Copymaster assignment) and the second part covers inter-process communication (same as the IPC assignment).

IV. CHANGES IN OPERATING SYSTEMS DUE TO RESTRICTIONS

COVID-19 pandemic had a significant impact on the school year 2021/2022. Government's and school's health policies did not allow for more than 15 students to be in the same classroom for the lesson. Our groups for operating systems usually consist of 24-27 students, so divided subgroups can have up to 14 students. This division led us to several options for teaching:

- Continue with lessons without changes, the absent part second group can use available materials on LMS Moodle for self-learning;
- Reduce the content of lessons and try to teach reduced content of two lessons in one lesson;
- Create online plenary lesson.

We decided to choose the third option, creating an online plenary lesson. It has several benefits such as:

- Possibility of recording, and later processing of recordings to create an online curriculum;
- Reducing pressure on common lessons, and the increasing amount of time for consultations;
- Unpredictable changes in health policies do not affect the organization of the subject.

One of the most significant drawbacks of the plenary lesson is that it can create additional time pressure on students. To compensate for this, we decided to make pretests as a voluntary activity and we increased the number of students in a team for IPC from two to three.

V. RESULTS FROM STUDENT SURVEY

In the school year 2021/2022 we collected 54 responses from the students' survey. We had 269 students this year, so 20.07% of students participated in the survey.

We selected several questions from the survey, that can help evaluate organization during face-to-face teaching with smaller groups and during distance teaching:

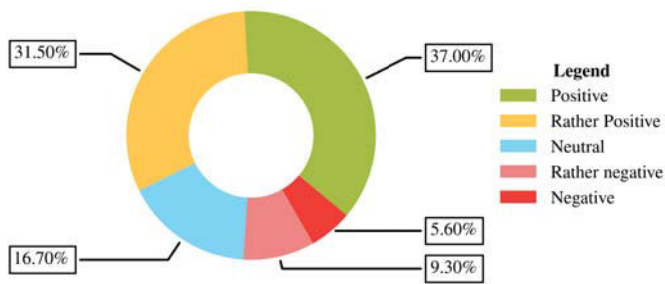


Figure 1. Answers to the question "How do you evaluate the method of organizing exercises based on a plenary lesson?"

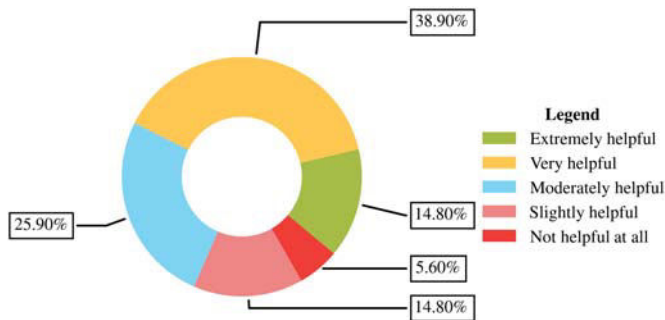


Figure 2. Answers to the question "How helpful were your teachers in the subject Operating systems during online study?"

A. How do you evaluate the method of organizing lessons based on a plenary lesson?

This question focused on students' views on plenary lessons and their consideration of their organization.

Students considered the organization of the plenary lesson to be positive as seen in the figure 1. 68.5% of students consider plenary lessons as a positive method, 16.7% of them view it as neutral, and 14.9% view plenary lessons as negative.

B. How helpful were your teachers in the subject Operating systems during online study?

Results from answers to question *How helpful were your teachers in the subject Operating systems during the online study?* are shown in figure 2. 79.6% of students considered teachers as helpful during distant learning, while 20.4% did not.

C. How stressful was distance learning for you during the COVID-19 pandemic on the subject Operating Systems?

Figure 3 shows a visualization of the responses to the question "How stressful was distance learning for you during the COVID-19 pandemic on the subject Operating Systems?". We gave the students 5 possible answers to this question ranging from "extremely stressful" to "not stressful at all". The results were surprising, with a majority of 33.30% of students responding that distance learning was "not stressful at all", followed by a 27.80% response rate of students who responded "slightly stressful" and 22.20% who responded "moderately

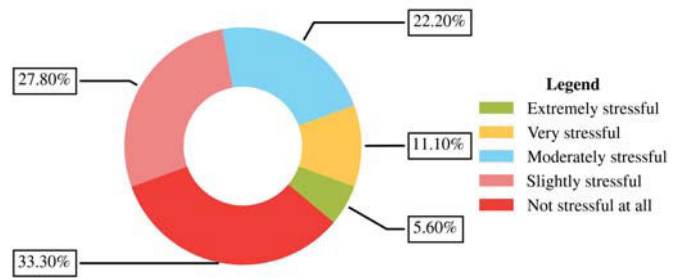


Figure 3. Answers to the question "How stressful was distance learning for you during the COVID-19 pandemic on the subject Operating Systems?"

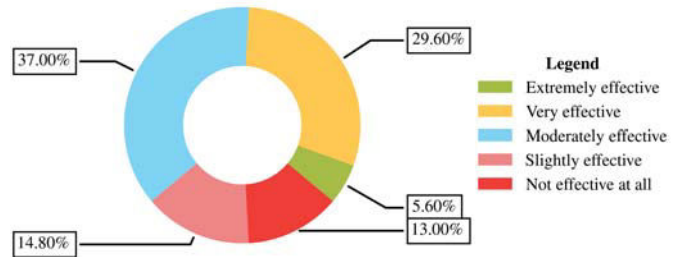


Figure 4. Answers to the question "How effective was distance learning for you in terms of understanding the material covered and the possibility to verify the presented theory in practice?"

stressful". 11.10% of students answered that distance learning was "very stressful" for them. Only 5.60% of students chose the answer "extremely stressful". If we consider the combined response rates for "not stressful at all" and "slightly stressful", we get a very positive rate of 61.1% of students, which gives distance learning very positive feedback.

D. How effective was distance learning for you in terms of understanding the material covered and the possibility to verify the presented theory in practice?

On the other hand, the answers to the question "How effective was distance learning for you in terms of understanding the material covered and the possibility to verify the presented theory in practice?" were not as satisfactory as the answers to the question about stress during distance learning, as shown in figure 4. In this question 37% of students responded that understanding during distance learning was only "moderately effective", followed by 29.60% of students who found it "very effective". The answer "slightly effective" was chosen by 14.80% of students, and the worst answer "not effective at all" was chosen by 13.00% of students. Unfortunately, only 5.60% of students considered the effectiveness of distance learning as "extremely effective".

E. How much time did you spend on distance learning in the subject Operating systems on average per week?

Based on the pie chart in figure 5, the majority of students selected the option "3-5 hours" and "5-7 hours". Both options

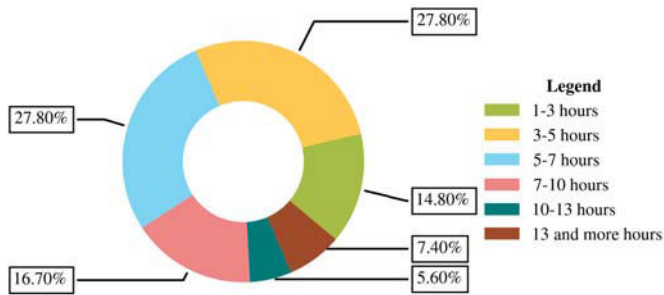


Figure 5. Answers to the question "How much time did you spend on distance learning in the subject Operating systems on average per week?"

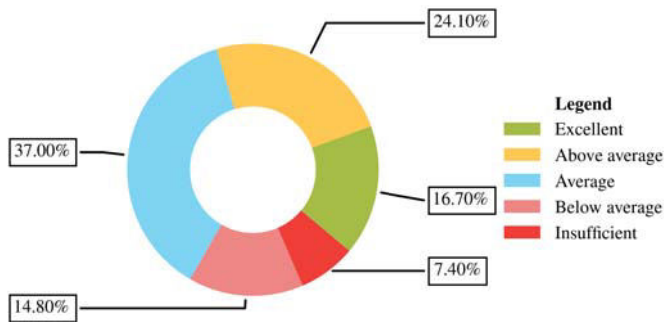


Figure 6. Answers to the question "How do you generally perceive distance learning compared to face-to-face teaching?"

were selected by 27.80% of students. Next, the most popular option was "7-10 hours" answered by 16.70% of respondents. 14.80% of students spent only 1-3 hours on the Operating systems subject. The least marked options, "10-13 hours" and "13 and more hours" were selected by 5.60% and 7.40% of all respondents. Overall, 70.4% of students spend up to 7 hours on distant learning in the Operating systems subject.

F. How do you generally perceive distance learning compared to face-to-face teaching?

In figure 6, we can see the answers to the question "How do you generally perceive distance learning compared to face-to-face teaching?". The most popular answer was "average" with a rate of 37.00% of students, followed by 24.10% of students who responded, "above average". 16.70% of students perceived distance learning as "excellent" compared to face-to-face learning. With negative answer "below average" responded by 14.80% of students and the worst answer "insufficient" was chosen by 7.40% of students.

VI. RESULTS FROM LMS MOODLE

LMS Moodle provides¹ various statistics and logs that can be analyzed. After each plenary lesson, we published a recording from it and placed it in Moodle.

Figure 7 shows a filtered view for each plenary lesson recording from LMS Moodle protocol logs. Two the lowest

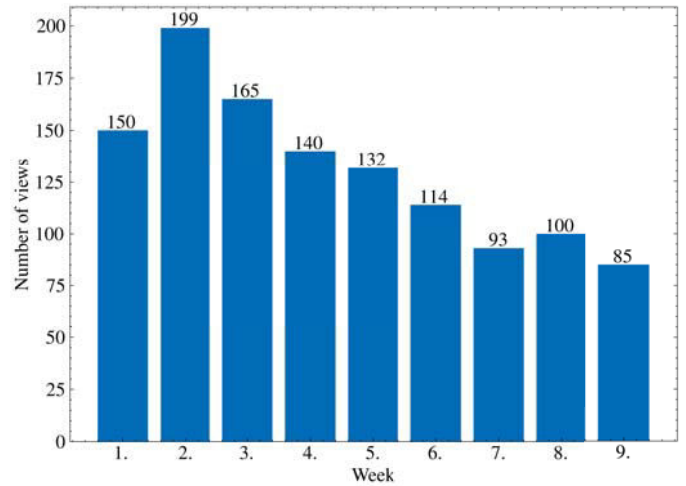


Figure 7. Views for each week's recording from LMS Moodle

number of views were the 7th week - 93 views - 34.57% of all students and in the 9th week, 85 views - 31.60% of all students in the school year 2021/2022. The highest number of views was in the 2nd week, 199 views - 73.98% of all students.

VII. DISCUSSION

In this section we propose and discuss hypotheses regarding plenary lessons and their impact on students. In our evaluation, we use data from sections V and VI, data from previous articles and another questions from survey.

A. Plenary lessons are useful for students and they are more satisfied with organization.

As was discussed in subsection V-A, students were pleased with the organization of the lessons. This is also supported by answers to the questions "How stressful was distance learning for you during the COVID-19 pandemic on the subject Operating Systems?" shown in the figure 3 and "How helpful were your teachers in the subject Operating systems during the online study?" shown in the figure 2.

For more than 50% of students, distant learning was not stressful or only slightly stressful. This can be also proof, that organization of plenary lessons was acceptable for students.

B. Plenary lessons and reduction of mandatory activities did not increase time pressure on students

In section V-E we showed results from a student survey regarding the time that they spent on Operating systems subject. It was crucial to keep time pressure on the current level or to reduce it. Students in previous years [1] [5] complained about amount of work on assignment compared to other subjects.

Mandatory lessons last 3 hours - plenary lesson and consultation lesson. The lecture lasts 2.25 hours, but it is not mandatory and many students do not attend it.

We can compare results discussed in section V-E with results from student's survey from school year 2020/2021 shown in the figure 8. As can be seen, the average spent time

¹https://docs.moodle.org/400/en/Main_page

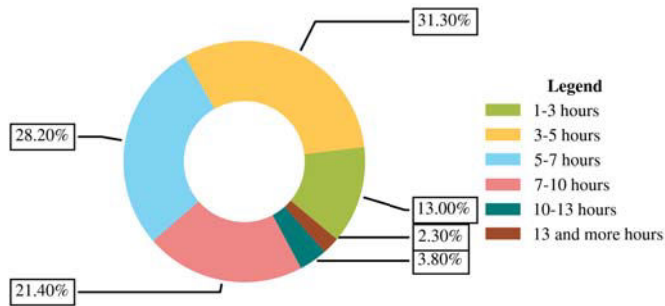


Figure 8. Answers to question "How much time did you spend on distance learning in the subject Operating systems on average per week?" in school year 2020/2021

remained very similar in the school year 2021/2022 compared to the previous year. The most significant difference is in the category where students spent 13 or more hours per week. This difference was up to 5.1%. In a deeper analysis of these answers that marked 13 and more spent hours, they usually tried to complete every available activity. These differences can be caused by the smaller statistical sample in the student survey for the school year 2021/2022.

Generally, additional lessons (plenary lessons) did not create additional time pressure on students on average. Students that decided to complete every available activity for points could feel more under time pressure compared to the students with the same intention in the previous school year.

C. Recordings from plenary lessons were useful for students.

Study materials on the Operating systems subject were highly evaluated by students, as is discussed in [1]. Recordings can serve as a complement to existing materials.

Students actively used recordings based on data and discussion in section VI. The second week has the highest number of views. The most possible explanation for this is that in this lesson were introduced the fundamentals needed for the first assignment, Copymaster. The seventh week has the second lowest number of views. There were holidays during this week and we decided to publish old recordings from the previous year without substitution for the plenary lesson. The content of this recording was shared memory, which is one of the easiest curricula needed for the second assignment, IPC, so good coverage in existing study materials also could affect the number of views.

The number of views decreased periodically from the second week to the end of the semester. It was expected as similar behavior of students can be observed in subject lectures, the number of students attending the lecture is decreasing during the semester.

These recordings have one significant issue. They are long and have usually 1.5 hours on average. In the future we will probably try to improve the length of recordings, dividing them into short videos ranging from 2 to 10 minutes. Improvement along with the interactive web page described in [8] can help students and they can focus more on the harder curriculum.

In this article, we introduced the concept of plenary lessons and evaluated their overall impact on Operating systems subject in the school year 2021/2022. For evaluation, we used mainly results from the student survey for the school year 2021/2022, but we also supported survey results with results from the student survey for the school year 2020/2021.

Plenary lessons have proved to be a great addition to the Operating systems subject. In our standard lessons, we had much more time for consultations, students even rated plenary lessons as a positive addition to the subject.

One of the observed properties was time pressure on students. Analysis of results from the student survey for the school year 2021/2022 and 2020/2021 showed that time pressure remained very similar. However, in the student survey for the school year 2021/2022 more students marked options 10-13 spent hours or 13 and more spent hours on average per week on assignments and activities in the Operating systems subject. Time pressure remained the same for most of the students, some students focusing on completing every activity could feel increased time pressure compare to the previous school year.

Plenary lessons gave us another advantage - the ability to record the lesson and publish the recording to LMS Moodle. We analyzed protocol logs from LMS Moodle and sections with plenary lesson recordings were visited by most of the students. Besides that, some students were connected to the plenary lesson.

Changes in Operating systems subject in the school year 2021/2022 were successful. In the future, we will probably process recordings from plenary lessons, and divide them into smaller videos to help students navigate between complex curricula.

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