E-learning Can Reduce the Negative Impact of COVID-19 in Teaching Mathematics

J. Fialová* and M. Pokorný*
* Trnava University/Faculty of Education, Trnava, Slovak Republic
jana.fialova@truni.sk, mpokorny@truni.sk

2020 18th International Conference on Emerging eLearning Technologies and Applications (ICETA) | 978-1-6654-2226-0/20/$31.00 ©2020 IEEE | DOI: 10.1109/ICETA51985.2020.9379222

Abstract—**Blended learning represents a combination of face-to-face instruction in a classroom and e-learning. In several studies, we proved that it is a suitable method for teaching mathematics at our faculty. However, in a summer term of the academic year 2019/2020, it was not possible to have face-to-face lessons due to a pandemic situation caused by COVID-19. Thus, we have to use only e-learning. In the paper, we compare the results of the students taught by blended learning and e-learning and we prove that e-learning helps to reduce the negative impact of COVID-19 in teaching mathematics. Moreover, we declare that there is no significant difference between the results of daily and external students in the final tests.**

I. Introduction

Modern technologies have significantly influenced the way of mathematics teaching in the last twenty years. Nowadays, even little children widely use mobile phones, tablets, notebooks, and computers. Thus, it is absolutely natural to use these modern devices to reach teaching aims in mathematics.

It is well-known that mathematics should be learned by an active work of students, not by a transmission of knowledge from a teacher to students. A proper integration of modern technologies into mathematics teaching can make the learning process more active, which leads to the increase of the level of students' knowledge.

The methods of utilization of modern technologies into mathematics teaching have been developing. While forty years ago teachers used isolated programs to reach a concrete teaching aim or to obtain a concrete knowledge, nowadays schools and universities use learning management systems, e-learning, blended learning, and mobile learning. There are different definitions of these terms. For example, Khan [5] defines e-learning as an innovative approach for delivering well-designed, learner-centered, interactive, and facilitated learning environment to anyone, anyplace, anytime by utilizing the attributes and resources of various digital technologies along with other forms of learning materials suited for open, flexible, and distributed learning. By Hanzel [3], e-learning frequently occurs in solving problems in education. It represents a new approach to execution of education, which is based on utilization of software products. Blended learning is usually defined as a combination of a face-to-face lessons with a teacher and e-learning. This method is often considered as an ideal way how to integrate modern technologies into teaching to obtain a required teaching aim. In recent years, mobile learning has become more and more popular. Crompton [1] defines mobile learning as learning across multiple contexts, through social and content interactions, using personal electronic devices. Voštinár and Hanzel [12] state that tablets and mobile telephones are gradually becoming standard integral teaching aids in the current school environment. An example of mobile learning in mathematics teaching is presented for example by Voštinár [11].

There are many studies about efficiency of e-learning, blended learning, and mobile learning. However, the conclusion of their efficiency is not clear. Majority of studies prove a significant improvement of the level of students' knowledge. On the other hand, some studies underline that there is no improvement, or that the improvement is not significantly high. We think that we should agree with Žilková [13], who states that the quality of electronic education is primarily determined by the accurate e-content. The research of Horváth and Mišút [4] states that e-learning enables to decrease a number of contact hours without negative impact on the students' level of knowledge. Naturally, blended learning can be more efficient in teaching mathematics than a traditional face-to-face instruction only if it properly uses the advantages of ICT. It is generally known that pupils have to learn mathematics by their active work, not by reading and memorizing definitions, theorems and algorithms. Thus, it is very important to use interactive applications, which can make pupils to solve problems actively. Interactivity is one of the advantages of ICT integration, which cannot be reached by printed books. The importance of interactivity in mathematics teaching is stressed also in the study of Žilková et al. [14], who state that the interactive educational applets have potential to support inner motivation of children, as well as to increase the ability of children to recognize and to apply the pattern. Interactive applications can provide to students an immediate feedback, warn students about their mistakes and advise them how to solve the problem. Moreover, each student in a class can solve different problem and work at his own pace. Thus, integration of ICT into teaching mathematics changes the role of students from passive recipients to active learners.

As for mathematics teaching, our research, as well as the research of other authors, reveal that blended learning is a proper way to teach mathematics at secondary schools and universities. For example, it follows from the study of Malatinská et al. [7] that blended learning can increase the level of mathematical knowledge of the secondary school pupils. Moreover, it can improve their attitudes towards mathematics. As for university students, the study of Pokorný [8] prove that blended learning is efficient in teaching *Combinatorics and Data Processing*. Cheung and Slavin [2] found that ICT applications produce modest but positive effects on mathematics achievements in comparison to traditional methods. The study of Voštinár [10] confirms that the utilization of ICT within a discrete mathematics course will positively influence students' attitudes towards mathematics. The findings of Jeffrey et al [6] reveal that students show a strong liking for blended modes of learning. Moreover, blended learning offers a richer learning experience than either online or traditional modes of learning.

II. Description of the Research

A. Students

At our faculty, we prepare mainly future teachers at primary and secondary schools. The students, who want to become teachers at primary school, have to complete a three-year bachelor study of *Pre-School Elementary Pedagogy* and a two-year master study of *Primary Education Teaching*. During their study, they have to complete several courses from mathematics. These courses are usually taught by a combination of e-learning activities and face-to-face lessons. The suitability of this method for these students has been proved by our research. For example, Pokorný [9] states that the students taught by blended learning consider their final evaluation to be more objective and they are more satisfied with their final evaluation than students taught by a traditional way. The majority of the students consider e-learning materials and interactive applications to be useful, but they do not agree that e-learning suits them better than a face-to-face instruction. Thus, blended learning seems to be an ideal way of teaching mathematics these students.

B. Subject Mathematics in Elementary Education

During the master study, the students of *Primary Education Teaching* have to complete the subject *Mathematics in Elementary Education.* The subject is divided into two parts. The first part, *Mathematics in Elementary Education 1 (MEE1)*, is taught in a winter term and the second part, *Mathematics in Elementary Education 2 (MEE2)*, is taught in a summer term.

In the academic year 2018/2019, we used LMS Moodle system only for publishing study materials. In the following academic year, we started to use the system more actively.

Mathematics in Elementary Education 1

Mathematics in Elementary Education 1 was taught in a winter term by blended learning. Our students had the same number of face-to-face lectures and exercises as in the previous year. Moreover, we created a Moodle course for them.

The Moodle course was divided into nine parts plus an introduction. The introduction contains information about rating, previous students' reports about selected Hejný's environments and a forum. The first part of the course is depicted on Figure 1.

The nine parts of the course were: *Natural numbers, Word tasks in mathematics, Addition and subtraction, Multiplication and division, Rational numbers, Integers, Equations, Functions, and Constructivism in math education*. All parts contain a pdf file with notes to replace the live lecture for students who could not attend. Moreover, it also contains brief notes of face-to-face exercises and homework assignments.

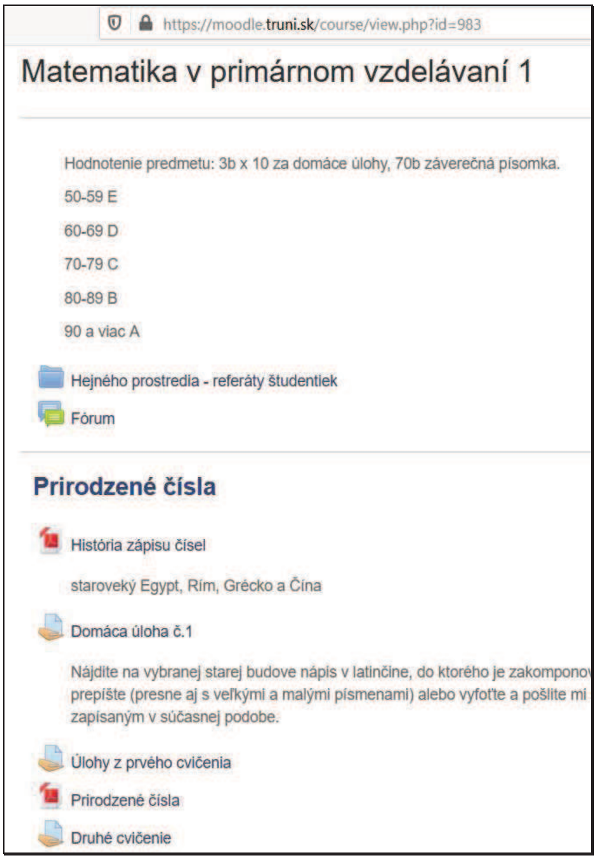

Figure 1. The appearance of the Moodle course

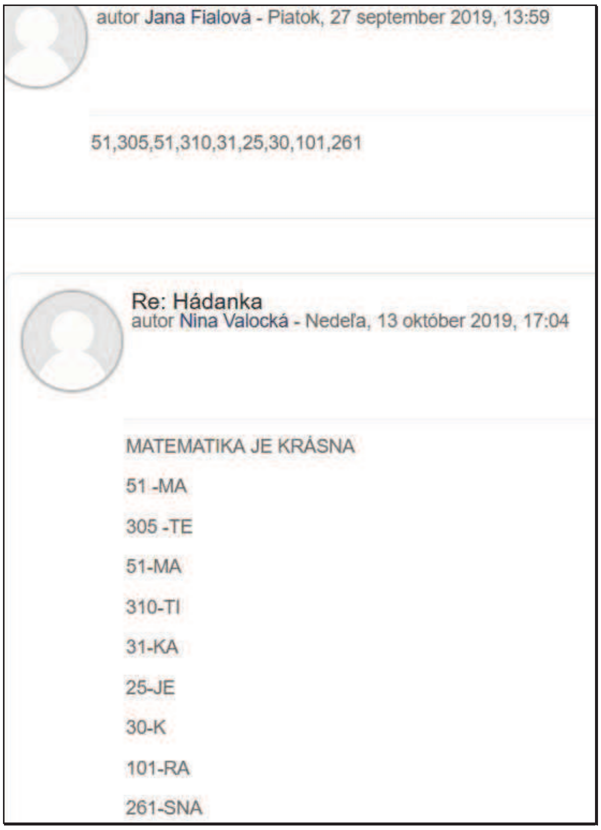

Figure 2. A riddle published in the forum

Students were given nine homework tasks. Solutions of the tasks were submitted directly to the Moodle system and were also evaluated there.

As for the final assessment, 70 points could be obtained for the final test and 30 points for homework. There was also a possibility to gain some extra points.

We also used a forum as a tool to publish additional more demanding task, which you can see on Figure 2. It took up to 17 days for the task to be solved by the first student. The task was following. The students obtained a series of numbers 51, 305, 51, 310, 31, 25, 30, 101, 261. They were asked what this series means. A message is encrypted by an alphabetic numeral system which we created in the class. The system was inspired by ancient Greek alphabetic systems. Numbers means letters as we can see in Table 1. During the face-to-face lecture, among other things, students transcribed a given number into a sequence of letters. But they had not obtained any additional information about the riddle, no remark that it is a text, or they need to use an alphabetic numeral system. Therefore, the task was so difficult.

At the end of the term, a questionnaire was given to the students. 62 of 68 students completed the questionnaire. One of the questions asked their opinion on the substitutability of the presented form of teaching for an online course. Nine students agreed that online course could fully supply the face-to-face lessons, 53 students think that online course is a useful addition to face-to-face

A – 1	B – 2	C – 3	D – 4	E – 5	F – 6	G – 7	H – 8	Ch 9
I – 10	J – 20	K – 30	L – 40	M– 50	N – 60	O – 70	P – 80	Q – 90
R – 100	S – 200	T – 300	U – 400	V – 500	W– 600	X – 700	Y – 800	Z - 900

Tab 1. Fictional alphabetic numeral system

Figure 3. Answers to the question 'Could online course supply the face-to-face instruction?'

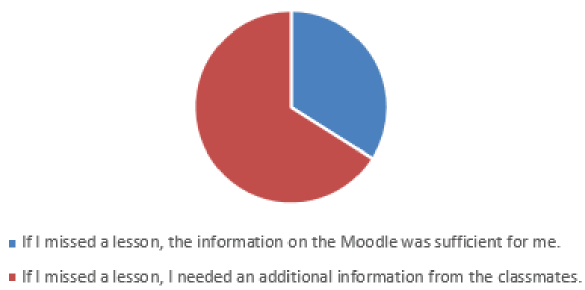

Figure 4. Answers of the students who missed any face-to-face lesson.

lessons and none of the students think that online course could never supply face-to-face lessons. (see Figure 3) We also asked students who missed a lesson if the information on the Moodle was sufficient for them (18 students) or they needed an additional information from their classmates who participated on the lesson (35 students). (see Figure 4) Other interesting outcome was the fact that only 23 students declared that they attended all face-to-face lessons.

Mathematics in Elementary Education 2

The second subject was *Mathematics in Elementary Education 2*, which started similarly as *MEE1*: two hours of face-to-face lectures per week and two hours of face-to-face exercises per week plus Moodle course. 66 students were enrolled in the course.

Since for this course a textbook has just been completed, the course is not divided by content. The main content of the course are geometry, logic, combinatorics and statistics. The first screen of the course, which is depicted on Figure 5, contains files of all study materials, information about praxis and other news.

As for the final assessment, 70 points could be obtained for the final test and 30 points for a report of a praxis and a report about selected topic of didactics of mathematics (submitted and evaluated in Moodle). There was also a possibility to gain some extra points.

The forum was much more used since face-to-face lectures were cancelled after three weeks from the beginning of the term, as a result of the pandemic situation caused by COVID-19. The students used the forum to communicate about tasks, to add their reports about selected topic and so on. We also met twice by MS Teams where we discussed problems from the textbook, which were chosen by students. Some students prefer email communication because of the anonymity. (The forum was public to all schoolmates.)

We think it was an advantage that we started blended learning right in the winter semester, as the students got used to this system and the cancellation of face-to-face teaching and the transition to purely online teaching went smoothly. So, the only change from the previous semester was the replacement of face-to-face lessons with more intensive use of the forum.

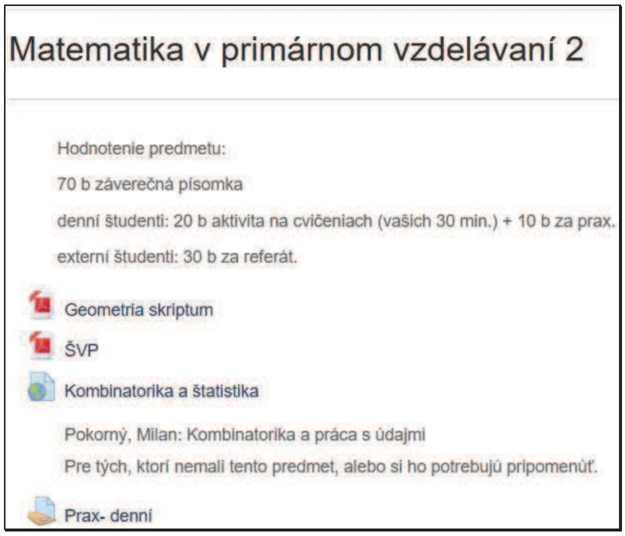

Figure 5. Appearance of the second Moodle course

C. Results of the Final Test and Final Assessment

At the end of each term of the academic year 2019/2020, the students have to pass the final test, which is a part of their final assessment. Now, we compare the results of the students in the final tests from *MEE1* and *MEE2*. The results are depicted in Figure 6. The average score in *MEE1* is 51.89 and the standard deviation is 11.09. The average score in *MEE2* is 52.24 and the standard deviation is 10.47. Note that the maximum score was 70 points. Firstly, we test the normality of differences between the results of *MEE1* and *MEE2* using the Shapiro-Wilk normality test. The value of the test statistic W is 0.990, which is in the 90% critical value accepted range [0.9684:1.0000]. Thus, it is assumed that the differences are normally distributed, and so we compare the results of *MEE1* and *MEE2* by a parametric t-test with paired samples. Since the probability of Type I error in this test is 83%, we accept the null hypothesis, which states that 'There is no significant difference between the results of the students from the final tests from *MEE1* and *MEE2'*.

Using the same method, we compare the final assessment of the students from *MEE1* and *MEE2*. The results are depicted in Figure 7. The average score in *MEE1* is 81.88 and the standard deviation is 14.16. The average score in *MEE2* is 80.50 and the standard deviation is 11.60. Firstly, we test the normality of differences between the final assessment of *MEE1* and *MEE2* using the Shapiro-Wilk normality test. The value of the test statistic W is 0.978, which is in the 90% critical value accepted range [0.9684:1.0000]. Thus, it is assumed that the differences

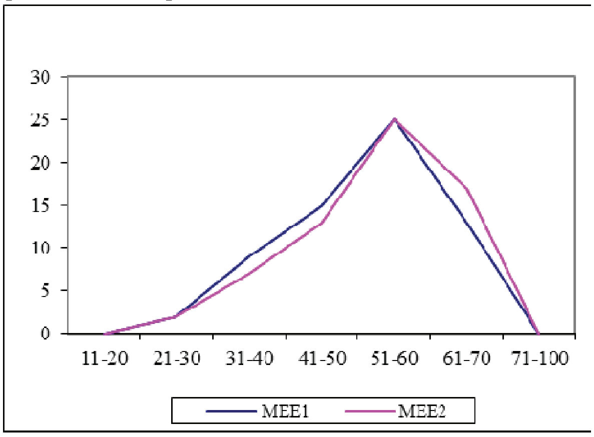

Figure 6. Results of the Final Tests

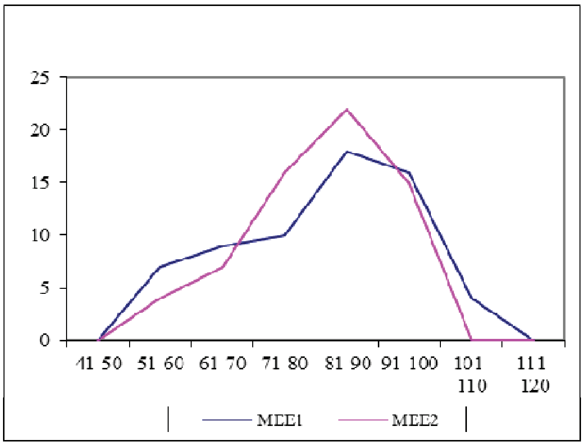

Figure 7. Final Assessment

are normally distributed, and so we compare the final assessment of *MEE1* and *MEE2* by a parametric t-test with paired samples. Since the probability of Type I error in this test is 45%, we accept the null hypothesis, which states that 'There is no significant difference between the final assessment of the students from *MEE1* and *MEE2'*.

However, there could be an objection whether there is a significant difference between the level of difficulty of the final test from *MEE1* and *MEE2*. The similar objection may concern the requirements on the final assessment from *MEE1* and *MEE2*. To refute these objections, we investigate the results of the student from the academic year 2018/2019, who were taught both subjects by blended learning. The average score from the subject *MEE1* in the academic year 2018/2019 is 1.79 and the average score from the subject *MEE2* in the academic year 2018/2019 is 2.23. Moreover, the statistical analysis reveals that in the academic year the subject *MEE2* was significantly more difficult than the subject *MEE1*.

To conclude, the statistical analysis does not prove any significant difference between the results of the students in the winter term (taught by blended learning) and in the summer term (taught by e-learning). Thus, we can say that the omission of the face-to-face teaching and its replacement with e-learning activities has no negative impact on the level of students' knowledge.

D. Results of the Daily and External Students

In our country, it is often mentioned that there is a significant difference in the level of knowledge of daily and external students. From 64 students in our experiment, 33 of them are daily students (group D) and 31 of them are external students (group E). In the following part of the paper we compare the results of both groups of students in the final tests, which we consider as a tool to measure the level of students' knowledge.

Firstly, we focus on the results from *MEE1*, which was taught by blended learning. The average score of the group D in the final test is 53.03, and the standard deviation is 10.57. The value of the test statistics W in the Shapiro-Wilk normality test is 0.951, which is in the 90% critical value accepted range [0.9458:1.0000]. Thus, it is assumed that the data is normally distributed. The average score of the group E in the final test is 50.68, and the standard deviation is 11.66. The value of the test statistics W in the Shapiro-Wilk normality test is 0.935, which is not in the 90% critical value accepted range [0.9430:1.0000]. Thus, it is assumed that the data is not normally distributed. From this reason, we do not compare the results of the groups D and E by a parametric t-test, but we use a non-parametric Mann-Whitney U test. The value of the test statistic u in the Mann-Whitney U-test is 0.788, which is less than the critical value 1.96. Thus, we accept the null hypothesis 'There is no significant difference between the score of the group D and E in the final test from *MEE1*.' The results of both groups are depicted in Figure 8.

Secondly, we focus on the results from *MEE2*, which was taught by e-learning without face-to-face instruction. The average score of the group D in the final test is 51.89, and the standard deviation is 10.00. The value of the test statistics W in the Shapiro-Wilk normality test is 0.952, which is in the 90% critical value accepted range [0.9458:1.0000]. Thus, it is assumed that the data is normally distributed. The average score of the group E in the final test is 52.60, and the standard deviation is 11.11. The value of the test statistics W in the Shapiro-Wilk normality test is 0.904, which is not in the 90% critical value accepted range [0.9430:1.0000]. Thus, it is assumed that the data is not normally distributed. Similarly to the case of *MEE1*, we compare the results by a non-parametric Mann-Whitney U test. The value of the test statistic u in the Mann-Whitney U-test is 0.438, which is less than the critical value 1.96. Thus, we accept the null hypothesis 'There is no significant difference between the score of the group D and E in the final test from *MEE2*.' The results of both groups are depicted in Figure 9.

To conclude, the statistical analysis of the results of the final tests from *MEE1* and *MEE2* does not reveal a significant difference. Thus, it is not possible to say that our external students have lower level of knowledge from the subjects *MEE1* and *MEE2* than their daily classmates.

III. Conclusion

The pandemic situation connected with COVID-19, which caused the change of teaching methods from face-to-face instruction into on-line or off-line forms in a very short time, caused a lot of problems at all types of schools, from primary schools to universities. A lot of teachers, who were used to teach only by face-to-face instruction,

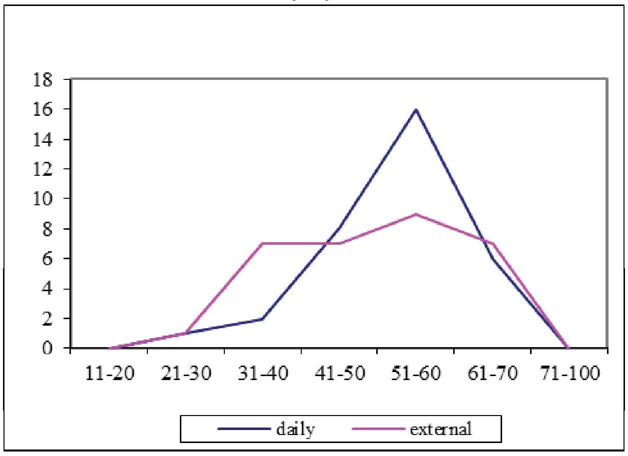

Figure 8. Results of Groups D and E in the Final Test from MEE1

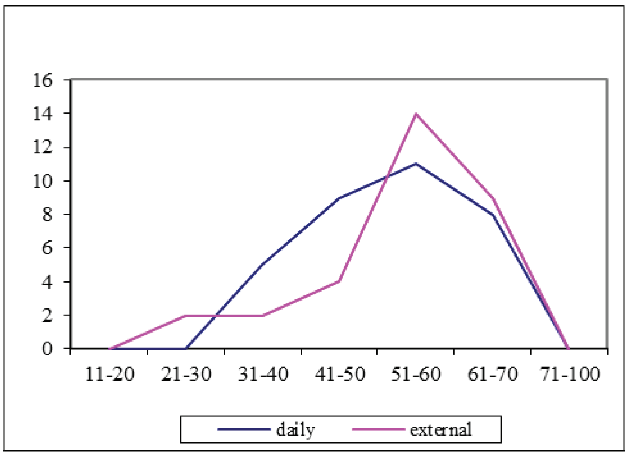

Figure 9. Results of Groups D and E in the Final Test from MEE2

did not know how to efficiently use the modern technologies to change the way of teaching without a negative impact on the level of students' knowledge. A great deal of teachers did not know how to realize on-line lessons, as well as how to prepare materials for e-learning to provide sufficient level of feedback. Moreover, some subjects are more suitable for e-learning, blended learning, and integration of modern technologies than the other subjects.

In the paper we prove that the change of teaching methods from face-to-face instruction into utilization of modern technologies does not have to automatically mean the reducing of the level of students' knowledge. The statistical analysis of the results of our students from the subject *Mathematics in Elementary Educations* reveals that e-learning (without face-to-face instruction) can be as efficient as blended learning. Of course, it is possible only if the students have a well-prepared teaching materials, which take into account the strengths of electronic materials, which cannot be reached by a classical printed materials. We are convinced that our experiment was successful thanks to the fact that we taught our students by a combination of face-to-face instruction and e-learning, so both we and our students were used to utilize ICT to reach teaching aim. Thus, we recommend to increase the share of subjects, which are taught by blended learning, also in times when schools are open. This leads to development of ICT competence of both teachers and students, which will help when the school is forced to change the face-to-face instruction into on-line or off-line forms.

The lower level of knowledge of external students is another often mentioned problem. It is clear that it is not possible to offer enough face-to-face lessons to external students. Thus, these students should have well-prepared materials, which offer sufficient level of feedback and support the active approach to learning, for example by integration of interactive applications. Our experience show that blended learning is suitable for reducing the gap between the level of knowledge of daily and external students.

Acknowledgment

The paper has been supported by the Cultural and Educational Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic (KEGA) under the projects KEGA 001UMB-4/2020 entitled *Implementation of Blended Learning into Preparation of Future Mathematics Teachers and Future Computer Science Teachers* and KEGA 003TTU-4/2018 entitled *Interactive Applications for Teaching Mathematics at Primary Schools*.

References

[1] H. Crompton, "A historical overview of mobile learning: Toward learner-centered education," Handbook of Mobile Learning, pp. 3-14. New York, NY: Routledge, 2013.

[2] A.C.Cheung, R.E. Slavin, "The effectiveness of educational technology applications for enhancing mathematics achievement in K-12 classrooms: a meta-analysis," Educational Research Review, vol. 9, pp. 88–113, 2013.

[3] P. Hanzel, "Možnosti elektronickej podpory vzdelávania v príprave učiteľov pre 1. stupeň ZŠ," Zborník Cesty (k) poznávání v matematice primární školy, Olomouc, 2004, pp. 107–112.

[4] R. Horváth, M. Mišút, "Rationalisation of educational process by e-learning," ICETA 2004, Košice : Elfa, pp. 11-13, 2004.

[5] B. Khan, *Managing e-learning strategies: Design, delivery, implementation and evaluation*. Hershey, PA : Idea Group Inc., 2005. ISBN 1¬ 59140-634-X

[6] L. M. Jeffrey et al., *Strategies for engaging learners in a blended environment*. Ako Aotearoa—The National Centre for Tertiary Teaching Excellence, 2012.

[7] S. Malatinská, M. Pokorný, P. Híc, "Efficiency of blended learning in teaching mathematics at primary school," Information, Communication and Education Application, Advances in Education Research, vol. 85, pp. 6–11, 2015.

[8] M. Pokorný, "Blended learning can improve the results of students in combinatorics and data processing," ISET 2019. Los Alamitos : IEEE Computer Society, 2019, s. 207-210. ISBN 978-1-7281-3387-4

[9] M. Pokorný, "Experience with e-learning in Teaching Combinatorics and Data Processing". MIPRO 2020, 43rd International Convention on Information, Communication and Electronic Technology. In print.

[10] P. Voštinár, "GeoGebra Applets for Graph Theory," Proceedings of EDULEARN17 Conference, Barcelona, 2017, pp. 10142-10148. ISBN: 978-84-697-3777-4

[11] P. Voštinár, "Pythagorean Theorem – Mobile Application," INTED 2018, pp. 0800-0805, 2018.

[12] P. Voštinár, P. Hanzel, "Mobile application – a tool for teachers, pupils and their families," APLIMAT 2016 - 15th Conference on Applied Mathematics 2016, Proceedings, 2016, pp. 1118-1125.

[13] K. Žilková, "Manipulating geometry course and its advantages and risks in e-learning education," / "Prednosti a riziká vzdelávania prostredníctvom e-learningového kurzu manipulačná geometria," XXVI. Didmattech 2013: New Technologies in Science and Education, pp. 222-227, 2014.

[14] K. Žilková, E. Partová, J. Gunčaga, "Design of educational applets for increasing children's abilities to recognize patterns," E-learning and smart learning environment for the preparation of new generation specialists, 2018, pp. 229-242. ISBN 978-83-66055-05-6