INTERNATIONAL JOURNAL OF EDUCATION AND INFORMATION TECHNOLOGIES
DOI: 10.46300/9109.2022.16.17 Volume 16, 2022

Comparison of face-to-face and online computer science education in high school

Petr Coufal,
University of Hradec Kralove, Faculty of Science,
Rokitanskeho 62, Hradec Kralove 500 03,
Czech Republic

Received: July 16, 2021. Revised: October 14, 2022. Accepted: November 21, 2022. Published: December 19, 2022.

Abstract— This study focuses on the analysis of regular face-to-face computer science instruction with online instruction in high school. Given the modernization of conventional teaching in schools, it would be a good idea to keep some elements of online teaching and allow students to learn remotely. What are the benefits of online learning on the development of students and their competencies? As part of the research investigation, we experimented with and compared the learning achievement of two groups of students in the subject of computer science. The first group was taught normally full-time at school, while the second group was taught online at home. As part of the research investigation, we compared their academic achievement in different areas of computer science and STEM (Science, Technology, Engineering, Mathematics), ranging from programming to working with robots. The results of the published research do not confirm statistical differences between online and face-to-face teaching. It follows that the different form of teaching does not affect the development and evaluation of the student and his academic achievements.

Keywords— Online learning, competencies, computational thinking, STEM, computer science, educational robotics

I. Introduction

THIS study focuses on the comparison of regular face-to-face computer science instruction with online instruction in high school. Until recently, it was unthinkable to implement conventional teaching without the presence of students in the school. In the context of the Covid-19 disease pandemic, face-to-face teaching in schools was reduced and was quickly replaced by online teaching. The new form of teaching could not be immediately implemented in all subjects because it was a challenge for teachers and students. Some subjects can be taught face-to-face and online at a comparable level. In our study, we compare the forms of teaching the subject of computer science in high school. In this subject, students acquire skills and knowledge that they can apply in other fields and everyday life. Students develop their skills, and competencies and acquire knowledge. Today's society places high demands on individuals; as Zounek states, the school should be a place for acquiring the necessary competencies, [1]. The Framework Curriculum for Education in the Czech Republic describes individual key competencies. "Key competencies represent a set of knowledge, skills, abilities, attitudes, and values important for the personal development and application of each member of society.", [2]. In our research, in addition to students' competencies, we are also concerned with computational thinking, which was already investigated by Seymour Papert in the 1960s, [3]. The exact definition of computational thinking varies, a rather wide definition is according to Jeanette Wing, [4], or according to ISTE (International Society for Technology in Education) and CSTA (Computer Science Teachers Association), [4,5,6,7,8]. However, what is important are the principles and practices with which students work. Students are learning to work with and learn from error, students are actively working and learning persistence to solve problems that they break down into smaller parts that are more solvable for them or their team. Teamwork, collaboration, and communication among students are important and prepare them for real life. In computational thinking, students actively develop other multidisciplinary competencies, such as communicative, social, and problem-solving competencies, [5,8].

II. MATERIALS AND METHODS

The main goal of this study is the comparison of face-to-face teaching with online teaching in the subject of informatics at secondary school. The comparison of selected forms of computer science teaching is carried out by a research experiment. For the statistical testing of students, their assessment obtained in the subject of computer science will be used. Another goal of this study is the implementation of online STEM teaching with elements of educational robotics.

In the experiment, the subject of computer science was observed for several reasons. The first is the easy transferability of the teaching content from face-to-face to online. Here it is important to mention the readiness of the teacher, school, and students to teach this subject online.

A. Teaching conditions at school

The research investigation was conducted in a small secondary school with one class in each grade. The school has approximately 100 students and 15 teachers. This small number of students and teachers allows for a family-like environment in the school and the teaching of each subject. The advantage of having a small number of students is that the students and teachers know each other better, also communication is better. The school has the advantage of providing students with their computer equipment in the form of a student laptop that students can use in their classes. In addition to the laptop itself, students can license the programs and applications used in the classroom free of charge. Which makes teaching easier for teachers and students. Students can use the programs and applications throughout their studies, not just during classroom instruction. The school building is covered with sufficient Wifi network signal to cover all the devices of the students and enable them to learn seamlessly. The school also allows students to use their own devices in the form of a BYOD (Bring Your Own Device) model, which brings many benefits to the students, teachers, and the school, [9,10,11]. As part of their curriculum, students take a computer science course every year of their studies. In the first and second years, they have two lessons per week, in the third and fourth years, it is one lesson per week. This number of teaching hours is sufficient to teach this subject and to fill its content with individual computer science topics.

In the second year of secondary school, students study 2 hours a week in the subject of computer science. This subject this year includes algorithmization, creating flow charts, programming, working in a spreadsheet calculator including creating tables, graphing formulas and macros, as well as working with databases. And also from the STEM field, it is programming educational robots, [12,13,14,15]. All the topics are discussed concerning the student's field of study and their specialization, meaning that it is a closer introduction to the topic. In the framework of algorithmization, students learn to create a simple algorithm and understand its creation, and the specifics of its notation and visualization. The creation of algorithms is followed by the creation of flowcharts, which teach students computer science - algorithmic thinking, [16]. The creation of flowcharts is important for their further learning in programming. These topics allow students to develop their key competencies, for example, problem-solving, learning or, when working in a group, communicative or socio-personal competencies. This is a set of important competencies that are often multidisciplinary and important for the further development of students, [2]. Another extensive area of learning is spreadsheet work; specifically, the school uses Microsoft Excel in the classroom, which students can use free of charge as part of the school's Office 365 license. As part of learning to use this tool, students learn to use the spreadsheet environment, create and format spreadsheets, use conditional formatting, and use and create formulas and functions to work with text, numbers, and logic. In the spreadsheet calculator, students work with contingency tables, and database information, record and create macros by recording or using code and programming in a VBA (Visual Basic for Applications) environment, create two and three-dimensional graphs, create graphs in 3D maps and much more and important for practical use in life. In some topics, we use unplugged activities in the classroom to make it easier for students to understand or master the topic at hand, [17]. Unplugged activities are also suitable for traditional high school computer science classes; examples of activities can be found here, [18,19,20]. According to the above, it can be seen that most of the learning content can be easily taught online, for example, via video conferencing with students. Programming with educational robots is implemented so that students experience the construction, control, and programming of an educational robot, as well as try their hand at solving simple and typical STEM problems.

B. Description of the experiment

In our research experiment, we compare two different groups of students with different forms of instruction. One group is taught face-to-face, and the other is taught online via Microsoft Teams, which students use as part of their Office 365 school account.

C. Face-to-face teaching

Normal face-to-face teaching of the subject of Computer Science takes place in a traditional classroom, as students work on their own devices, and no dedicated computer lab is required. The teacher works on the teacher's computer and shares the desktop via a projector on a screen. All students can watch what is happening on the screen at the same time and can also work on their own devices. If they are unclear, they can ask the teacher right away, who can give them immediate feedback. In a face-to-face classroom, it is easier for the teacher to check on the students and their activities in class because they can watch the student's work live. However, students in regular classes have the opportunity to consult with the teacher in a limited way in the school environment, that is, in the morning and afternoon. For the assessment of students with a grade, face-to-face teaching is more suitable for checking students' independence. Face-to-face teaching also affects students in the form of socialization, direct communication, and group cooperation. Teaching took place according to the standard school curriculum in the subject of computer science, as mentioned earlier. The evaluation of students, which was the basis for our research, took place with an emphasis on the acquisition of skills acquired in teaching. It was possible to use their teaching materials, notes, and work files for regular assessment and testing of students. It was important for students to be able to use these materials, just

like in everyday life. Lessons are 45 minutes long and are always separated by a short break.

D. Online learning

Students taking classes in the Microsoft Teams online environment were taught according to the regular school schedule. Individual lessons were 45 minutes long, followed by a break. Classes were taught in a scheduled meeting that students accessed from home via their devices. During the lesson, the teacher shared the screen with the working tool in which the lesson was being taught, for example, a Microsoft Excel spreadsheet environment. Each lesson was recorded and available to students immediately after the lesson in the Microsoft Teams environment. This was a significant advantage that was praised by many students, as they can view everything on video repeatedly and as many times as they want. These recordings were used by students who were absent from the online classes and could easily compensate for what they had missed. In addition to these recordings, students were offered the possibility of individual consultation, which they could use repeatedly after discussion with the teacher. These peer-to-peer online consultations could also be conducted in the afternoon and evening, which was beneficial for many students who like to work late into the evening. In the case of checking in with students and sharing their work screens, more time is to be expected, and sometimes the checking-in may not be successful for all students. The big difference was in the part of teaching programming using educational robotics, where real robots were replaced by virtual robots that can be almost fully used for these purposes. Virtual robotics is a relatively new field that extends and enriches the possibilities of online programming education in schools and other STEM subjects, [21,22].

Students are continuously assessed in the course by a grade on individual tests, and they receive an overall grade on their final report card from these grades. In the course, it was important to test students' skills in real work, rather than searching for information on the Internet. Therefore, all student tests were also conducted in an online environment with a focus on their acquired skills. This allowed the students to use all materials and recordings of the online lessons. However, we cannot be sure that the work submitted was created independently by the student. These are the same conditions as in face-to-face teaching.

E. Description of the experiment

At the beginning of the experiment, it was necessary to pair two groups of studied students, based on their midterm grades in the computer science course. This is a necessary condition for the realization of the research experiment in this study. The control and experimental groups were the same at the beginning of the experiment according to the evaluation criteria and student results. Therefore, it was possible to carry out a research experiment based on other educational forms.

Student ratings are divided into five groups: excellent, commendable, good, fair, and poor. In our case, the groups represented the first three levels of assessment. At the beginning of the experiment, the groups of students were comparable. The second phase of the research experiment followed, namely the teaching of students in the control and experimental groups. Figure 1 shows the schematic of the research experiment. In the first group, called the control group, normal face-to-face teaching took place according to the curriculum. The second group, called the experimental group, was taught online according to the same curriculum. Both groups were regularly evaluated and tested during the course.

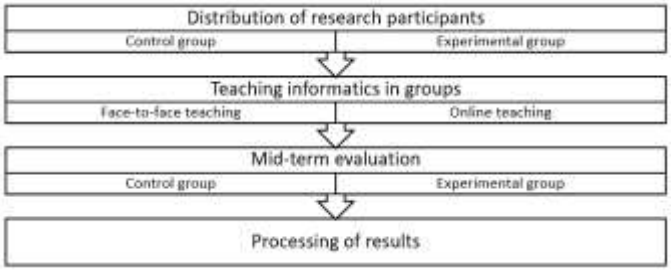

Fig. 1 Scheme of research in the control and experimental group of students

Based on the continuous assessment, the students also received an overall assessment for the report card. This is a half-yearly assessment of students. The student's overall final grade was one of five possible levels. These obtained levels of individual students in each group were then anonymized, grouped into tables, and statistically compared to verify the established research hypothesis.

F. Research aim and hypothesis

The Research Objective (RO) was chosen for this research investigation as follows:

RO: To analyze the effect of online computer science courses on the development of students.

The research objective chosen in this way corresponds to the focus of this study. To assess the difference between face-to-face teaching and online teaching, it is necessary to establish a suitable research hypothesis that can be tested statistically. In this study, the following hypothesis (H1) is chosen to be statistically tested. According to the test result, the hypothesis will be accepted or rejected, [23].

H1: The students taught by online computer science instruction are more successful than those taught traditional way.

III. Results

To test the validity of hypothesis H1 (The students taught by online computer science instruction are more successful than those taught traditional way.), we formulate the null and alternative hypotheses.

H_{01}: There is no statistically significant difference between the average level obtained in the subject of computer science in the Experimental Group and the average level obtained in the Control Group.

H_{A1}: There is a statistically significant difference between

the mean levels obtained in the two groups.

To test the hypotheses, we chose the nonparametric two-sample Mann-Whitney test at the significance level $\alpha = 0.05$. We tabulated and anonymized the student levels obtained. From this table, for further calculation of the Mann-Whitney test, we constructed a table of the pooled ranking of each pupil according to their obtained levels. Subsequently, T_E and T_C, [23], were calculated from the data using the formula.

$$T_E = 339$$

$$T_C = 327$$

We then performed check calculations according to formula (1) to verify the validity of the relationship, [23], where n = 18 and m = 18.

$$T_E + T_C = 1/2\ (n + m)(n + m + 1) \quad (1)$$

The U_E and U_C calculations followed, [23],

$$U_E = nm + 1/2\ n(n + 1) - T_E = 324 + 171 - 339 = 156 \quad (2)$$

$$U_C = nm + 1/2\ m(m + 1) - T_C = 324 + 171 – 327 = 168 \quad (3)$$

We then performed further check calculations and verified the validity, [23].

$$U_E + U_C = nm \quad (4)$$

$$156 + 168 = 324$$

At the same time, we determined the test criterion by:

$$U = \min(U_E, U_C) = 156$$

The critical region, [23]:

$$U < w_{\alpha;m;n} \quad (5)$$

We find the value of $w_{\alpha;m;n}$ for specific values of $\alpha = 0.05$; m = 18 and n = 18 in the Mann-Whitney test tables, [24]. The observed value from the tables is $w_{0.05;18;18} = 99$, which we compare and find.

$$156 \not< 99$$

Therefore, we do not reject and accept hypothesis H_{01}, that is, there is no statistically significant difference between the average level obtained in the Experimental Group and the average level obtained in the Control Group.

To verify the results of the Mann-Whitney test, we proposed to use another test, namely the Chi-square test of independence for a four-field table, which we created based on the rules about merging columns and rows in a contingency table. However, considering the values in the created table, ie size n = 36 and the number of theoretical frequencies less than 5, we have to proceed using Fisher's combinatorial test for the four-field table, [23,25].

To test the validity of hypothesis H1 (Students taught online in computer science are more successful than students taught in the traditional way.), we formulate the null and alternative hypotheses using Fisher's combinatorial test.

H_{01}: There is no statistically significant difference between the average level obtained in the subject of computer science in the Experimental Group and the average level obtained in the Control Group.

H_{A1}: There is a statistically significant difference between the mean levels obtained in the two groups.

The chosen significance level is $\alpha = 0.05$.

From the generated table, we perform probability calculations for each table configuration, which are then summed to obtain the resulting probability. We compare the value of the resulting probability with the selected significance level $\alpha = 0.05$ and decide whether to accept or reject the hypothesis. For our table, the value of the resulting probability is p = 0.2286, it is higher than $\alpha = 0.05$ and therefore we do not reject hypothesis H_{01} and accept it, that is, there is no statistically significant difference between the mean level obtained in the Experimental group and the average level obtained in the Control group.

The result of Fisher's combinatorial test for the four-field table verified the validity of the Mann-Whitney test result for the comparison of the Control and Experimental Groups in our research.

IV. DISCUSSION

Research hypothesis H1 asserted that students taught online are more successful. It is evident from the statistical results of our research that this hypothesis was not confirmed, we did not demonstrate a statistically measurable difference. Each form of teaching has its benefits and shortcomings for teaching. It is determined by the perspective of the students, and their parents, then it is the perspective of the teachers and the school. Face-to-face teaching is a traditional form that is recognized and preferred by society today. Form of online education is perceived as an incomplete education, rather only as a possible replacement. If we realize what the future of society will be, it is necessary to change education in this direction as well. The findings in this study may help change that. Therefore, it was not possible to choose a more suitable form of teaching for our research. This is beneficial because a common prejudice was that children only play on the computer and don't learn. Our research has disproved this preconception and confirms educational trends that are moving learning to an online environment. And even in the areas of STEM education, [26]. This is a unique matter in our education system, but with the tools for online education, it is now easier to implement online or hybrid education. Importantly, online or hybrid learning is considered a full-fledged type of learning. Which is one of the findings of our research. Students often prefer a combination of face-to-face and hybrid forms of education [27].

V. CONCLUSION

The contribution of this study is the main objective of the study: a comparison of face-to-face teaching with online teaching in the subject of informatics in high school. The comparison was made by a research experiment of control and experimental groups of students. Their academic achievements and evaluations were monitored. Student evaluations were used to statistically compare groups and test the research hypothesis.

Another goal of this study was the implementation of online teaching in the field of STEM with elements of educational robotics. This form of teaching is new and untested and can have a positive effect on student development and assessment [28]. Several tools of online robot simulators in 2D and 3D space were used for online teaching [22]. Online educational robotics was very positively evaluated and liked by the students.

Other research opportunities

In the next part of the research, we want to focus more on students' competencies. Again, we want to compare face-to-face teaching with online teaching. We also want to focus on students' IT thinking and its development during online teaching. We see great potential in research in the fields of STEM and STEAM (Science, Technology, Engineering, Arts, Mathematics), among students and the development of their competencies. Students' key competencies are an important element of education, and monitoring and testing their development in individual areas is beneficial for students and teachers. We want to expand the research and also monitor gender differences in various computer science courses, we want to focus on the field of programming and educational robotics. Another recommended direction for our future research is to focus on inclusive education in the fields of STEM and STEAM, [29].

ACKNOWLEDGMENT

This paper has been supported by: Specific research project of University of Hradec Kralove, Faculty of Education in 2021 No. 2126.

References

[1] Zounek, J. ICT v životě základních škol. 1. Vyd. Praha: TRITON. 2006. ISBN 80-7254-858-1.

[2] Národní ústav pro vzdělávání . Rámcový vzdělávací program pro základní vzdělávání. Praha: VÚP. 2007.

[3] Stager, G. Seymour Papert (1928–2016). Nature 537, 308 (2016). https://doi.org/10.1038/537308a

[4] Wing, J. M. 2006 Computational thinking. Commun. ACM 49, 33–35.

[5] Lessner, D. ANALYSIS OF TERM MEANING "COMPUTATIONAL THINKING". Journal of Technology and Information Education, 6(1), 71-88. 2014. doi: 10.5507/jtie.2014.006

[6] Wing, J., M. Computational Thinking: What and Why?. 2010. Available online: https://www.cs.cmu.edu/~CompThink/resources/TheLinkWing.pdf

[7] Frank, F. Výuka informatiky a podpora informatického myšlení pomocí legorobotů na gymnáziích. ISVK FPE 2018: Sborník příspěvků 8. Interdisciplinární studentské vědecké konference doktorandů FPE: Plzeň, 2018, s. 24-34. ISBN 978-80-261-0828-3.

[8] Operational Definition of Computational Thinking for K-12 Education. International Society for Technology in Education (ISTE) a Computer Science Teachers Association (CSTA). 2011. Available online: https://cdn.iste.org/www-root/Computational_Thinking_Operational_Definition_ISTE.pdf

[9] Parsons, David & Adhikari, Janak. (2016). Bring Your Own Device to Secondary School: The Perceptions of Teachers, Students and Parents. Electronic Journal of e-Learning. 14. 67-81.

[10] Adhikari, Janak & Mathrani, Anuradha & Scogings, Chris. (2017). A Longitudinal Journey with BYOD Classrooms: Issues of Access, Capability and Outcome Divides. Australasian Journal of Information Systems. 21. 10.3127/ajis.v21i0.1693.

[11] Schellenberg, D. Analyzing the Impact of BYOD in Secondary School English Classrooms. 2018. Graduate Department of Education in the University of Ontario Institute of Technology. Available online: https://ir.library.ontariotechu.ca/handle/10155/969

[12] Li, Y.; Wang, K.; Xiao, Y.; Froyd, J.E. Research and Trends in STEM Education: A Systematic Review of Journal Publications. Int. J. STEM Educ. 2020, 7, 1–16.

[13] Koncept STEM. In: Národní ústav pro vzdělávání. Národní ústav pro vzdělávání, 2001. Available online: http://www.nuv.cz/p-kap/koncept-stem

[14] Siregar, N.C.; Rosli, R.; Maat, S.M.; Capraro, M.M. The Effect of Science, Technology, Engineering and Mathematics (STEM) Program on Students' Achievement in Mathematics: A Meta-Analysis. Int. Electron. J. Math. Educ. 2019, 15, 1–12.

[15] Bybee, R.W. What Is STEM Education? Science 2010, 329, 996.

[16] Gonda, D.; Ďuriš, V.; Tirpáková, A.; Pavlovičová, G. Teaching Algorithms to Develop the Algorithmic Thinking of Informatics Students. Mathematics 2022, 10, 3857. https://doi.org/10.3390/math10203857

[17] Sigayret, Kevin & Tricot, André & Blanc, Nathalie. (2022). Unplugged or plugged-in programming learning: A comparative experimental study. Computers & Education. 184. 104505. 10.1016/j.compedu.2022.104505.

[18] Computer Science Education Research Group. CS Unplugged. 2022. University of Canterbury. Available online: https://www.csunplugged.org/en/

[19] Cicirello, Vincent. (2013). A CS Unplugged Activity for the Online Classroom. The Journal of Computing Sciences in Colleges. 28. 162-168.

[20] Yıldız, Merve & KARAL, Hasan. (2021). A Computer Science Unplugged Activity: CityMap. International

Journal of Computer Science Education in Schools. 5. 14-27. 10.21585/ijcses.v5i2.110.

[21] Alsoliman, Badr. (2022). Virtual Robotics in Education: The Experience of Eighth Grade Students in STEM. Frontiers in Education. 7. https://www.frontiersin.org/articles/10.3389/feduc.2022.950766/abstract. 10.3389/feduc.2022.950766.

[22] Coufal, P., Helvich. J., Macinka. M. Virtual Robotics in Education at Elementary School. In: DIVAI 2022: 14th international scientific conference on Distance Learning in Applied Informatics. Praha: Wolters Kluwer, 2020. ISBN 978-80-7676-410-1.

[23] Chráska, M. Metody pedagogického výzkumu: základy kvantitativního výzkumu. 2007. Praha: Grada. Pedagogika (Grada). ISBN 978-80-247-1369-4.

[24] Zaiontz, Ch. Mann-Whitney Table. 2021. Available online: https://www.real-statistics.com/statistics-tables/mann-whitney-table/

[25] Preacher, K. J., Briggs, N. E. Calculation for Fisher's Exact Test: An interactive calculation tool for Fisher's exact probability test for 2 x 2 tables. 2001. Available online: http://www.quantpsy.org/fisher/fisher.htm

[26] Felder, R. STEM education: A tale of two paradigms. Journal of Food Science Education. 2021. 20. 8-15. 10.1111/1541-4329.12219.

[27] Nikolopoulou, K. Face-To-Face, Online and Hybrid Education: University Students' Opinions and Preferences. Journal of Digital Educational Technology. 2022. 2. ep2206. 10.30935/jdet/12384.

[28] Chiang, FK., Zhang, Y., Zhu, D. et al. The Influence of Online STEM Education Camps on Students' Self-Efficacy, Computational Thinking, and Task Value. J Sci Educ Technol 31, 461–472 (2022).

[29] Leibnitz, G. M., Gillian-Daniel, D. L., Greenler, R. M. C. C., Campbell-Montalvo, R., Metcalf, H., Segarra, V. A., ... & Sims, E. L. (2022). The inclusive professional framework for societies: changing mental models to promote diverse, equitable, and inclusive STEM systems change. Frontiers in Sociology, 6, 784399.

Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

Petr Coufal designed and implemented the research investigation. Petr Coufal processed the data and wrote this study.

Creative Commons Attribution License 4.0 (Attribution 4.0 International , CC BY 4.0)