

# Time Efficiency of Online Education in Technical Subjects Without Decreasing Didactic Effectiveness During the COVID-19 Pandemic\*

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This contribution is about the time and didactic efficiency of electronic education in training of future specialists in the field of applied informatics. We created two groups of students within our research: experimental and control group. Both groups had to create a mutual goal during the educational process (1 semester) – to design and program a robotic arm controlled by Arduino. The experimental group worked in the TinkerCad environment which is an online simulation playground aimed directly for designing and programming projects based on the Arduino platform. The control group did the experiment the conservative way: the education process was done by giving the students physical equipment with the necessary electronic components. The results of this experiment show us the time efficiency in the favor of online education, while the didactic efficiency reached the same level in both groups.

**Keywords:** time efficiency; online education; robotics arm

## 1. Introduction

Online education has become a standard part of education beside its classic form by personal attendance. Huge number of teachers and educators use it to overcome the limitations of big distances from their students, in which case personal attendance would be ineffective in timely and other manners. Although not all subjects in schools could be completely transformed into an online course. Online education is also impossible to implement completely in elementary and secondary schools. This fact was shown in the latest situations due to the viral infection COVID-19 which did not only spread rapidly since January 2020 in Europe but also globally and forced schools and education institutions to temporarily close [1, 2]. The most difficult situation arose in elementary schools where first grade students learn to read and write. In this case direct contact with a teacher is required and parents could not substitute this. Only time will tell how big impact this fact will bring to our society [3] and to its developments of skills and knowledge. We can state that the situation in the case of secondary schools was somewhat more favorable, and online education was more acceptable among the students. Despite that, plenty of subjects in secondary schools require personal attendance, laboratory practice for example [4, 5]. In this contribution we point to the method we used to settle with this situation in the case of technical oriented subject, where we could not imagine other form of education than personal attendance so far.

Researches regarding didactic efficiency in the

last 20 years [6–8, 24] suggest that the efficiency of perception and remembering is directly proportional to the number of sensors which are activated during mastering knowledge. Various methods are used to enhance didactic efficiency, like the Inquiry-Based Learning: “*Tell me and I forget it. Show me and I remember it. Let me use it and I understand. . .*”. According to Mayer [9] the biggest importance in knowledge acquisition is on sight (83% of information), auditory perception (11%), eventually other sensors that extend sense-perception (touch, smell, taste). At the same time, however, they state that the portion of each component of remembering the given information, for instance by using online interactive environments, is the following: approximately 30% is determined for perception, 20% for hearing and 10% for reading [9].

According to the previous definition, an online environment such as TinkerCad develops not only the function of sensory perception, but also of the intellectual perceptions. By using it, students also get into the essence of the object whilst by progressively exaggerating the illustrative aspect, there is also an increase in the potency of understanding and recognition of the examined topic. Using these forementioned environments are required mainly on the abstract level of thinking since students are not only developing their ideas, they are creating foundations of logical thinking as well whilst developing their programming skills [10].

Didactic efficiency as one of the elemental prerequisite for an education tool (in this case the TinkerCad online environment) depends especially on the fact how the educational content can be

transformed into theses according to the requirements of the student's profile, whom the didactic tool is designed for. Detection of the level of didactic efficiency (its increase or reduction) tends to be a problematic step among pedagogic researches. Utilizing online simulation environments is generally considered to be a very good aid to increase the interest of students towards the examined topic since its task is to support the development of cognitive and intellectual expertise, hence learning something new. Our statements are based on researches [11–18] saying the diversity of learning methods can positively affect the perception of information. Didactic efficiency of online simulation environments can be particularly difficult to quantify and therefore the foremost method of collecting relevant results (verifying didactic efficiency) is considered to be the project form of education. According to Henrich [19, 20], project form of education allows the students to present creativity and critical thinking. With this method we are able to analyze the extent and quality of their knowledge, expertise of application, pace of solving exercises, etc.

In the next sections we present the results of realized researches aimed at the detection of time efficiency from the perspective of didactic efficiency during the usage of online simulation environments due to COVID-19 and classic form of education.

## **2. Experiment – Comparing Didactic Efficiency during the use of Simulation Software TinkerCad with Classic Form of Education regarding Time Efficiency**

There are multiple means of determining efficiency of educational process, mainly by didactic efficiency, time efficiency and, naturally, with exams by which we are able to determine the quality and quantity of acquired knowledge. By time efficiency we mean time needed for task realization. Personal attendance is a standard form of education for professional training of future experts in the field of applied informatics, in which students are able to use their acquired knowledge and skills from other subjects. In the academic year 2019/2020 a big number of teachers and educators was forced to adapt their education process to online courses due to the spreading viral infection COVID-19 which closed the doors of almost every school in the world. Slovakia was no exception. Teachers of practical technics subjects not only needed new forms to continue with their education process but also explain the topics and help developing students' skills and knowledge, which is normally acquired by personal attendance.

Our team did an experiment in the winter semester

of the academic year 2019/2020 in order to determine the time efficiency of education processes during the usage of the TinkerCad simulation environment compared to the classic form of education. We evaluated the working method as the level of acquired skills and knowledge in the subject “robotic systems” during the winter semester. This subject was accomplished with the form of personal attendance in the winter semester (students represent the control group in the experiment). Supplemental activities were created within this subject which aided the straightforward verification of acquired knowledge and skill of students from previous subjects, such as Computer architectures, Assorted Chapters of Software and Hardware Technologies, Programming Chapter I and II. The subject Computer architectures is a technically oriented subject for the students of Applied informatics. With its content it focuses to the field of logic systems, electrical and electrotechnical components which together lay the basis of computers on the part of internal architecture. The subject Assorted Chapters of Software and Hardware Technologies is a supplemental subject to the previous subject, Computer architectures. In these subjects, students program their self-designed simple electrical circuits in the Multisim simulation environment, therefore students have real experiences with simulation programs. Multisim, from National Semiconductor, allows the students to design and create their own simple electrical circuits, such as binary clocks, code conversion, etc., whilst since version 14 they can use an embedded language for programming, which is similar to the C programming language. Subjects Programming Chapter I and II train the students from the basics for the role of a software developer in various of programming languages, particularly in C, Java and Python. Based on these facts we can state that both groups (experimental and control) have identical entry knowledge in the perspective of quality and quantity.

Students included in the experiment during summer semester of academic year 2019/2020 represent the experimental group which was forced to online courses due to COVID-19 and the quarantine it brought. Students of this experimental group utilized the TinkerCad online environment for the subject Robotic systems by creating an account. This online environment includes all the necessary elements for designing and creating a robotic arm fulfilling the requirements given by the teacher. One of the benefits of this online environments for teachers is progress tracking which clarifies the real work of students (whether the assignment was in fact done by them or it was plagiarized). Utilizing online environments overcomes the danger of pos-

sible damages to the components by the yet unprofessional usage by students. Online environments manage to host a significantly bigger number of students during the lesson than it is possible by personal attendance. The online environment acts as cloud storage space at the same time allowing the students to return to their unfinished projects at any time and progressively preserving their work while working on it. In fact, this feature enables cooperative work on the same project by multiple students with change tracking as well, either from school or from home. From the perspective of the teacher the most useful feature is tracking time spent working on a project, which also aids our research among the others.

A physical laboratory for work with Arduino was available for the control group during the winter semester including the necessary components to create the robotic arm. Designing and building the robotic arm (Fig. 1) is part of the educational process for future experts in the field of automotive industry (absolvents are going to work as programmers in the automobile plant Jaguar and Land Rover – based 10 kilometers from the university). The goal of students included in the control group was to accomplish the same assignment given to the experimental group within the classic form of education (personal attendance). The robotic arm had to be remotely controlled by Bluetooth technology, therefore students in both groups (control and experimental) had to create their own complex solution both in hardware and software part.

The robotic arm is controlled by six servomotors.



**Fig. 1.** The robotic arm, which was realized by students from the control group.

All of the components are driven by the Arduino UNO central control unit. The arm can move by the axes X, Y and Z, and use a pair of pliers. The structure is made from hard plastic parts, printed by a 3D printer. Both the arm and the control unit were attached to a wooden board preventing it from falling due to movement force.

The number of students in both groups was identical (40 students both). This situation was based on the number of students signed up to the subject and their grouping in the beginning of the semester, which we had to accept.

Process of research:

- (1) creation of control and experimental group,
- (2) creation of good quality measuring procedures,
- (3) proceeding with the experiment,
- (4) understanding the data,
- (5) verifying the validity of used statistical methods,
- (6) data analysis and interpretation of results.

The goal of this experiment was to verify the didactic efficiency of using simulation software for assignments of the subject Robotic systems aimed to determine the level of skills and knowledge among the students of applied informatics. The efficiency of this method had to be compared with the efficiency of classic education process, simulation vs. physical manipulation with the devices. For this instance, time for solving tasks was measured (in seconds), as well as the quality of the solutions. Quality was evaluated using a score system created by the course teacher. The project solutions were grouped into two parts: hardware part and software part (Table 1).

In Table 1 the variable *Group* represents the team where student belonged to. Variables *HW\_score*, *SW\_score*, *HW\_time* and *SW\_time* shows the amount of time needed for the student to figure out a hardware (HW) and software (SW) solution, respectively the score they reached for that solution.

To answer the questions according to our research we needed to create hypotheses. These hypotheses are formed as null hypothesis:

- H0 (1): No statistically significant difference between Control and Experimental groups based on the variable *HW\_score*.
- H0 (2): No statistically significant difference between Control and Experimental groups based on the variable *HW\_time*.
- H0 (3): No statistically significant difference between Control and Experimental groups based on the variable *SW\_score*.
- H0 (4): No statistically significant difference between Control and Experimental groups based on the variable *SW\_time*.

Comparison of middle values of this data is required to verify any significant differences between the Control and Experimental groups. We needed to verify whether these data files originate from a normal grouping provided we wanted to use any of the parametric methods for the comparison. Every variable was put through Lilliefors normality test, the resulting value for all four variables were below 0.01 (Table 1, Fig. 2). According to this, all four variables are normally grouped.

Besides normality of the variables, equality of variance of individual variables in both groups (experimental, control) required for the two-sample t-test (parametric method). For this instance, we used (Table 2, Fig. 3) Levene's test

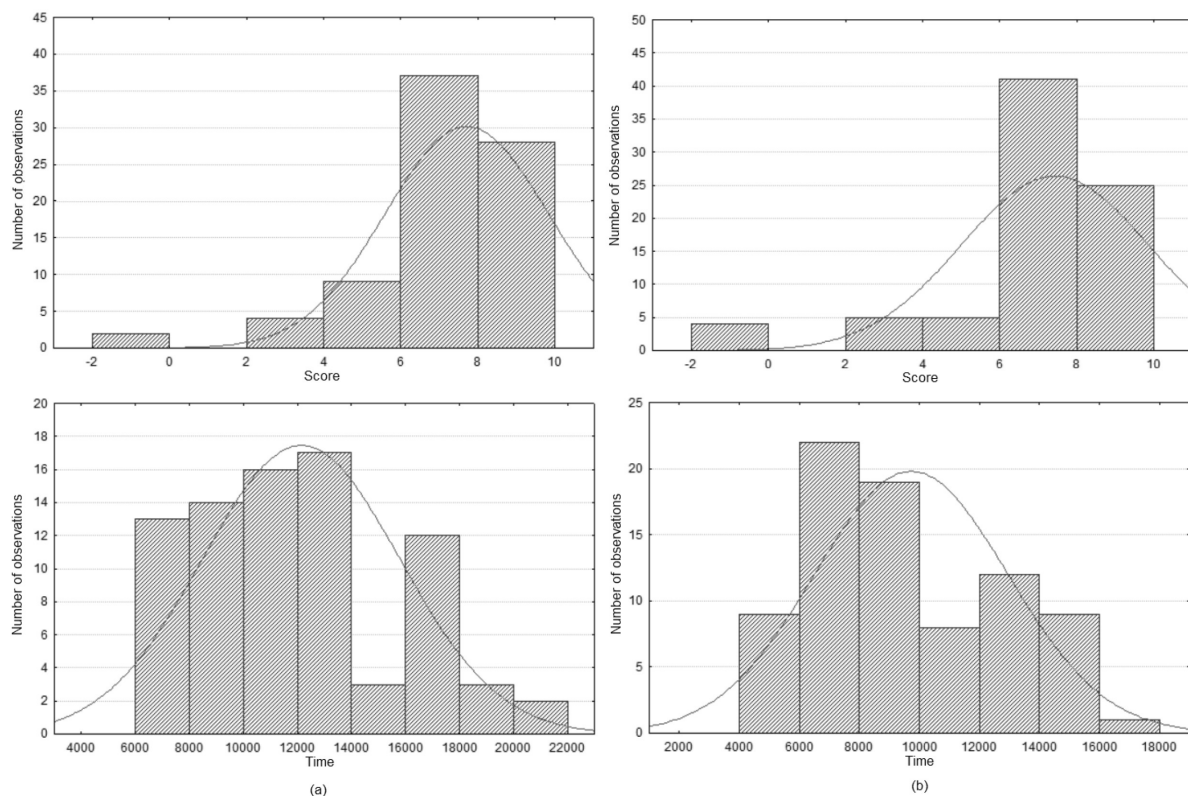
[22] which is based on variation analysis of absolute values in centered observations [23].

In Levene's test there is a value which resulted in the around 0.05. Since only the SW\_time variable showed the Levene p value higher than 0.05, only this variable fulfills the variety conditional of both Control and Experimental groups. In this case, the two-sample t-test (Table 3) can be used on SW\_time. On the other variables we need to use a non-parametric alternative.

Based on the two-sample t-test we can state that the p-value is lower than 0.05. This fact denies our H<sub>0</sub> (4) hypothesis and confirms that there is a statistically significant difference between the Control and the Experimental group in the amount of

**Table 1.** Example of recorded data from experimental and control group, from the perspective of earned scores for hardware and software solution of the assignment

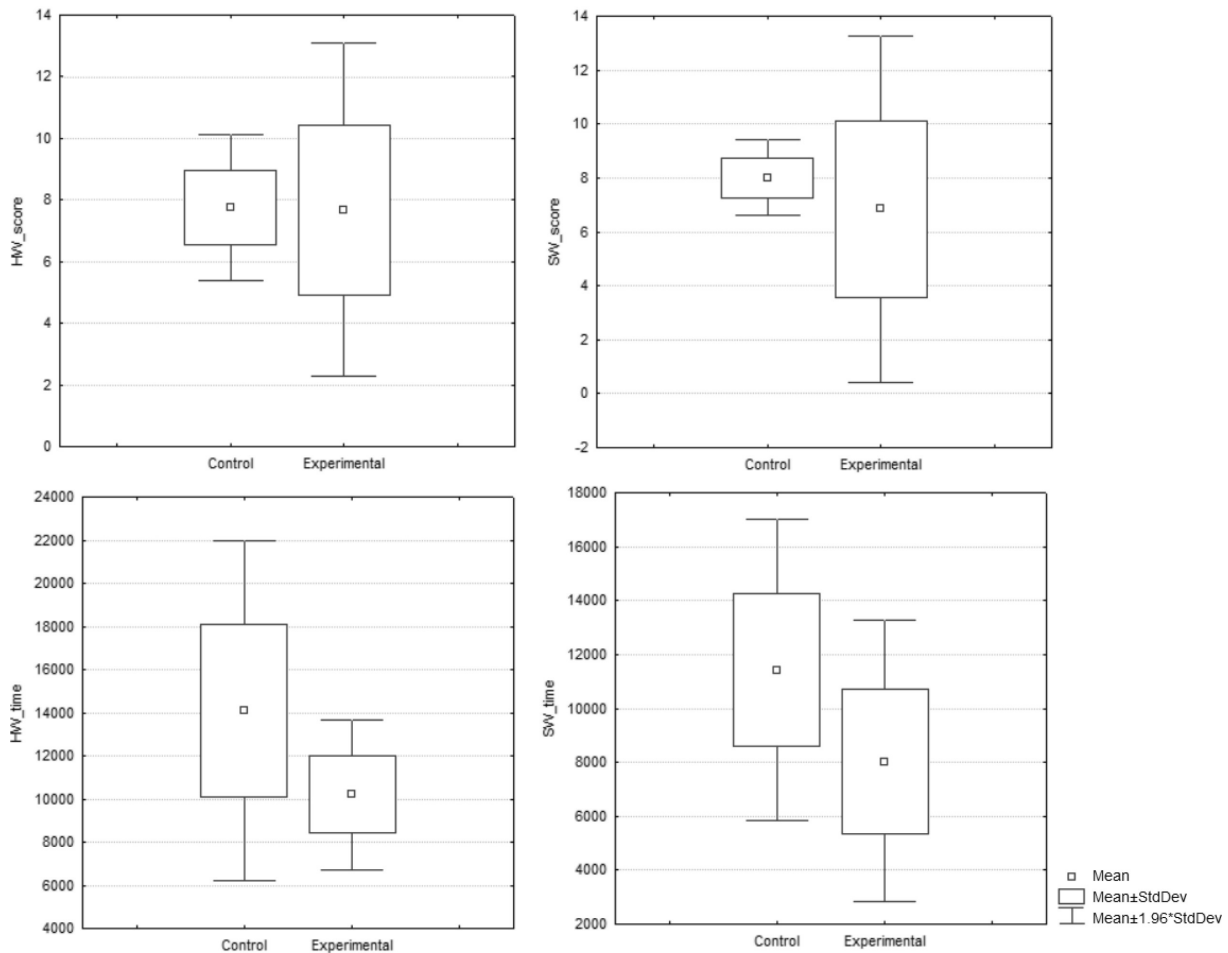
| Group        | HW_score | HW_time (seconds) | SW_score | SW_time (seconds) |
|--------------|----------|-------------------|----------|-------------------|
| ...          | ...      | ...               | ...      | ...               |
| Control      | 6        | 19026             | 7        | 15143             |
| Control      | 6        | 19208             | 7        | 15335             |
| Control      | 6        | 21123             | 7        | 15508             |
| Control      | 6        | 20795             | 7        | 14834             |
| Experimental | 8        | 12960             | 3        | 9504              |
| Experimental | 10       | 8640              | 10       | 6048              |
| Experimental | 10       | 11232             | 10       | 11232             |
| Experimental | 8        | 12096             | 5        | 6912              |
| ...          | ...      | ...               | ...      | ...               |



**Fig. 2.** Histogram of the frequency of variables HW\_score, HW\_time (a), SW\_score and SW\_time (b).

**Table 2.** Levene's test of variables HW\_score, HW\_time, SW\_score and SW\_time

|          | Standard deviation Control | Standard deviation Experimental | Levene F(1, sv) | Levene sv | Levene p |
|----------|----------------------------|---------------------------------|-----------------|-----------|----------|
| HW_score | 1.214                      | 2.759                           | 15.40637        | 78        | 0.000186 |
| HW_time  | 4020.070                   | 1784.671                        | 41.43179        | 78        | 0.000000 |
| SW_score | 0.716                      | 3.270                           | 62.54973        | 78        | 0.000000 |
| SW_time  | 2842.432                   | 2662.667                        | 0.71225         | 78        | 0.401278 |

**Fig. 3.** Box diagrams depending on the variables HW\_score, HW\_time, SW\_score a SW\_time.**Table 3.** Two-sample t-test for the variable SW\_time

|         | Mean Control | Mean Experimental | t        | sv | p        |
|---------|--------------|-------------------|----------|----|----------|
| SW_time | 11431.55     | 8035.20           | 5.515195 | 78 | 0.000000 |

**Table 4.** Mann-Whitney U test for variables HW\_score, HW\_time a SW\_score

|          | Sum of orders Control | Sum of orders Experimental | p-value  |
|----------|-----------------------|----------------------------|----------|
| HW_score | 1490.000              | 1750.000                   | 0.210963 |
| HW_time  | 2050.000              | 1190.000                   | 0.000035 |
| SW_score | 1645.000              | 1595.000                   | 0.809894 |

time needed for the SW solution part of the assignment. By this determination we can state the student of the Experimental group needed less time to solve the SW part of the assignment.

The rest of the hypotheses, namely H0 (1, 2, 3),

required a non-parametric alternative to get confirmed. For this process we used the Mann-Whitney U test which verifies whether the difference in average values between the two groups are statistically significant. Results are included in Table 4.

The values in Table 4 deny our null hypothesis  $H_0$  (2) on the level of significance, which means there is a statistically significant difference between the Control and the Experimental group in the variable HW\_time. Based on the shown values, however, the rest of the hypotheses,  $H_0$  (1) and  $H_0$  (3), are not being denied.

Our analysis confirmed the occurrence of statistically significant difference in the time values between the Control and the Experimental groups. However, there is no statistically significant difference in the score values. Tables 3 and 4 are showing higher values of time as well in the case of the Control group. This result indicates a better pace of hardware and software solution in the Experimental group, since the scores of quality were nearly identical.

### 3. Discussion

According to [2], one of the very important factors in the success of e-learning during the COVID-19 pandemic was information technologies. Although Blended Learning appears as the best alternative for project-based learning, during the COVID-19 pandemic, asynchronous learning with ICT support was used, which was considered to be the most suitable alternative to the traditional way of education. During the COVID-19 pandemic and the lockdown in the field of education, was changed mainly the way of teachers and students communicate. We have come to a same opinion as [4], that the pandemic lockdown had a significant impact on teachers and researchers. In order to be able to continue teaching, we had to apply new methods.

With these new methods we can evolve students' knowledge and skills the same as in classic form of education.

The results of the presented analysis confirm a better time efficiency of online course via TinkerCad in the technically oriented subjects aimed towards constructing and programming a robotic arm in comparison of a classic education process (personal attendance). Our methodology shown itself as a more time effective solution for working on SW and HW projects. However, there was no rise of skills and knowledge by using the methodology presented by us. Final conclusion: even technically oriented subjects can reach similar results via online courses under a significantly less amount of time.

### 4. Conclusion

The current view of online education has changed significantly, especially in the context of the COVID-19 pandemic. The ways were used teachers in online education (in the past) have to change now. In this paper, we focused on the evaluation of the results achieved by students in the control group before the pandemic and on the results of online education during the pandemic. During the implementation of the experiment, we tried to adapt the process of online education to the student's condition so that it corresponds to the classical (full-time) form without of decreasing didactic effectiveness.

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