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Challenges of Blended versus Online Learning with Arduino for Teachers and Students

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Abstract: The paper provides a comparative analysis of blended learning versus fully online learning of informatics course using Arduino. The aim of the research is to find out which teaching method leaves students more satisfied in learning the basics of electronics and programming. Until the Covid-19 pandemic, teaching took place in a computer classroom, with project-based learning in teams, while all teaching materials were uploaded to Moodle e-course. The advantages of blended learning on Arduino projects are active learning by doing, student collaboration and peer learning, the physical presence of the teacher with his immediate feedback and support. The disadvantages are the limited time to complete the Arduino projects, the need for a sufficient number of Arduino kits, the possibility of hardware failure, and the uneven contributions of student team members. Due to the transition to fully online teaching during the Covid-19 pandemic, the Autodesk Tinkercad Circuits web-based software was chosen. This software provides a virtual Arduino simulator for creating, programming and testing Arduino circuits, and managing a virtual classroom. The advantages of online learning with Arduino are increased effort and motivation of individual students, avoidance of electronic component failures and reduced frustration due to errors. The disadvantages are technical problems, communication problems, such as the lack of direct contact with the teacher and each other, and the lack of development of practical skills. Nevertheless, the research of two generations of first-year students of informatics (N=72) shows that they are more satisfied with online learning on Arduino projects than with blended learning, and this difference is statistically significant ($t(70)=3.91$; $p<0.01$). Therefore, Tinkercad Circuits can be used as an educational tool in regular classes to make learning the basics of electronics and programming more interesting and successful.

Keywords: Online learning, Arduino, Tinkercad, Virtual classroom, Learning satisfaction

Introduction

Although digital learning tools and platforms have been around for decades, they have become an indispensable part of education after the Covid-19 pandemic. The major challenge of using e-learning for teachers is the need to design lessons that make the most of technology and the e-space and actively engage students in learning. Nowadays, it is not enough to use presentation tools and a learning management system (LMS) to complement traditional teaching. To achieve the best results in online learning, it is necessary to reorganise the teaching process and use different pedagogical approaches. Therefore, teachers may need technological, pedagogical and organisational support as well as additional time to develop teaching materials and deliver the lessons (Elshami et al., 2021). E-learning brings a shift from traditional teaching methods by supporting multiple interactions between students, teachers, and learning content through technology. No less important are communication tools and communities that allow students to discuss and share their questions, thoughts, ideas, and results with each other and with the teacher. Fully online learning enables flexible and mobile learning for students, ensures the availability of content 24/7, allows students to track their own progress, and offers personalised learning. At the same time, online learning has some disadvantages. Students may struggle due to reduced social contact, lack of digital skills, lack of self-discipline and loss of motivation, or problems with technology and Internet access. Teachers are often concerned about student identification and cheating on online tests (Newton, 2020). Some studies show that the percentage of students who admitted to cheating in face-to-face and online courses is

almost the same (32%), although many students believe (74%) that it is easier to cheat in online courses (Online Education). Therefore, hybrid or blended learning where a teacher combines face-to-face and online teaching is a good way to get the best out of both approaches.

Arduino in Education

The Arduino platform with a programmable microcontroller is the leading "do-it-yourself" (DIY) tool used in STEM education, enabling students to develop computational thinking and learn programming principles as well as important engineering and science concepts (https://www.arduino.cc/education/). There are numerous examples of the use of Arduino as a learning tool at different levels of education (Ling & Wah, 2019; Karaahmetoglu & Korkmaz, 2019; Roumen & Fernaeus, 2021; Kim & Lee, 2017). Arduino is affordable, open source, easy to use, and easy to assemble without soldering components. It can be coded and a variety of sensors give it the ability to collect and process real world data, and take appropriate action. There are many resources for teaching and learning with Arduino, including lessons preparations, articles and manuals, libraries of ready-made projects with schematics, programming code and explained building steps. Arduino lessons allow students to link knowledge from different fields (especially STEM), apply it to real problems and better understand the interactions of programme code with real hardware. (Kim & Lee, 2017).

Informatics and computer science education should be active, focused on creative thinking and problem solving, keeping in mind bridging the gap between the classroom and the demands of the labour market. It is not uncommon for people who succeed in school and university to experience difficulties and failures when faced with real-life problems (Bahadir, 2020). By using Arduino in class, students learn how to connect electronic components to an Arduino board, program a microcontroller, test and debug it until they create a functional system that interacts with its environment. In this way, students acquire applicable knowledge, develop critical thinking and problem-solving skills, as well as time and stress management skills (Krelja Kurelovic et al., 2020). Such courses, whether blended or online, provide students with an engaging learning experience. Arduino in education helps students acquire skills that will play an important role in future jobs driven by robotics, the Internet of Things, machine learning, artificial intelligence, and other emerging technologies (Krelja Kurelovic, 2022).

Methodology

Teaching Methods

In the 1st year of introductory informatics course, the Arduino platform was used for 15 hours of laboratory lessons. As all teaching materials and other resources were carefully selected, prepared and uploaded to the Moodle e-course, while the students' practical activities took place in the computer lab, it was a blended learning course. During the lab lessons, students used Arduino RFID kits to apply theoretical knowledge in practice. Using project-based learning, learning by doing, and peer learning methods, they built 5 interactive systems with Arduino, from simple to complex. They learned how to use different sensors to collect input data from the environment, process this data and perform an action. Each student had their own role in the team (connecting components, writing code, documenting, describing, and presenting the project using a systems approach), and with each new project, the roles changed (Krelja Kurelovic et al., 2020). This gave the students the opportunity to participate in each team role, collaborate, share knowledge, solve problems, and take responsibility for the overall success of the project.

The challenges for the teacher in such teaching are numerous. It is necessary to properly design and prepare all the learning materials, install the necessary software on the computers (Arduino IDE editor), provide enough Arduino kits for the students, regularly check the correctness of the components and the Arduino board (hardware damage is not uncommon), motivate the students to find a solution when an Arduino project does not work, manage the schedule, and remind the students of deadlines.

During the Covid-19 pandemic, all teaching took place online. In addition to the Moodle e-course where all learning resources were stored and communication took place, the Autodesk Tinkercad web-based software was chosen for the laboratory lessons, which were conducted in real time via webinar. Autodesk Tinkercad has a friendly user interface and provides a good user experience. Tinkercad Classroom (Figure 1) enables the creation of virtual classes where students use Tinkercad tools for 3D design, electronics, and coding, and teachers monitor students' progress and guide them (https://www.tinkercad.com/). Tinkercad Circuits was used

to create Arduino projects. It is an intuitive, user friendly, interactive circuit web editor where students can explore, connect and code using the Arduino board, electronic components (LEDs, resistors, capacitors, etc.), sensors or actuators on the component panel. Arduino circuits in Tinkercad can be coded using the Blocks code editor or with C++ in a text-based editor (Figure 2) which is similar to the Arduino IDE editor.

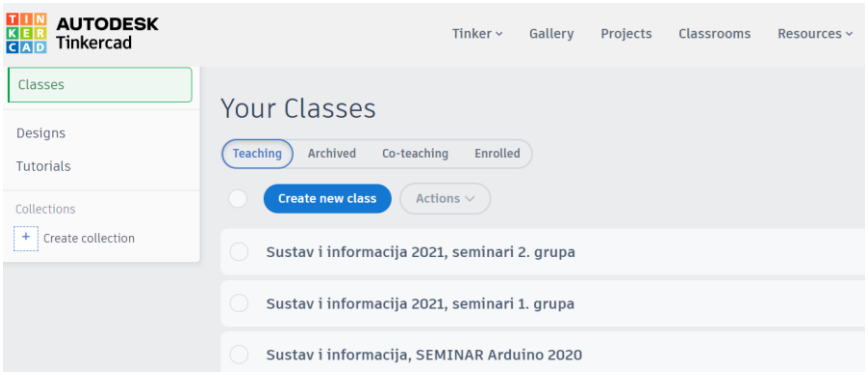

Figure 1. Tinkercad classes dashboard

Guided by the teacher's demonstration via video conferencing, students had to virtually assemble an Arduino system in Tinkercad and write a program that the microcontroller would execute. After coding, they had to test if the created system works, so the simulation runs in Tinkercad Circuits (Figure 2). Debugging is the most challenging step where a student improves their problem-solving skills, and Tinkercad's error console helps by reporting and flagging lines of code that need to be corrected. The teacher randomly asked the students to share the screen and show how their Arduino project works. It was a time for discussion and additional information, if needed. After the online class ended, the teacher checked the progress on each student's Arduino project in Tinkercad Classes and gave them feedback, which took a lot of the teacher's time.

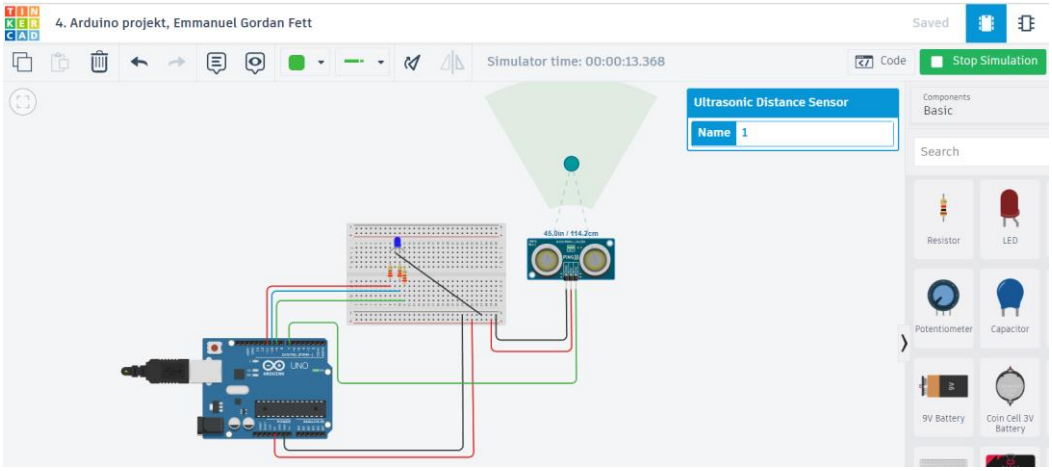

Figure 2. Simulation of Arduino project "distance sensor"

Compared to blended learning, in the fully online classes, each student worked individually on each Arduino project and had the opportunity to continue working on the project after the class ended. They had limited opportunities to collaborate and learn amongst peers, but were more engaged and involved. All communication and feedback from the teacher took place virtually using asynchronous communication tools.

Research Methods

The aim of the research is to determine whether students are more satisfied with blended learning or fully online learning during computer labs with Arduino. This is important for the teacher to improve their teaching and increase the student satisfaction with learning. Accordingly, the following null hypothesis is proposed:

H0: There is no significant difference in student satisfaction with blended learning or fully online learning using Arduino.

For the research, 1st year informatics students were surveyed over two years (2019–2020). At the end of the semester, students filled out a specially designed online questionnaire available on the Moodle e-course. Participation in the survey was anonymous and voluntary. To create the questionnaire on satisfaction with teaching and learning, similar studies were used and adapted to the needs of this research (Bahadir, 2020; Torrado & Blanca, 2022; Ling & Wah, 2019; Martin & Bolliger, 2022; Elshami et al., 2021). The questionnaire contained a demographic question (gender) and 8 statements on satisfaction with teaching and learning with Arduino. Students were asked to indicate the level of agreement with these 8 statements on a Likert-type scale (5=strongly agree, 1=strongly disagree). The last question was open-ended and optional, in which students could write what they liked or disliked about the Arduino lessons.

Results and Discussion

The research sample consists of 72 students. In 2019, there were 42 respondents with whom classes were conducted on-site, and using blended learning. A year later, there were 30 respondents with whom the teaching took place completely online. According to the population of students in informatics, where are more men than women, the sample includes 79% male and 31% female students.

The descriptive statistics of the questions on satisfaction with learning with Arduino are shown in Table 1. Students were mostly satisfied with Arduino lessons, although those in online classes expressed greater satisfaction. The fact is that there were not Arduino kits available in the on-site computer labs, 90 minutes was sometimes not enough to complete the tasks, and physical failures due to improper use of the electronic components were also not uncommon. The virtual simulator Tinkercad Circuits which was used in online classes solves most of the problems mentioned. Both groups of students are almost equally satisfied with the learning resources that were available in the Moodle e-course and with the feedback from the teacher. In the online learning, the teacher supported the students remotely in real time and gave them written feedback after class if needed.

Table 1. Descriptive statistics of responses to the questionnaire

Statements	Blended learning (N=42)	Online learning (N=30)
	Mean	*Mean*
1. I am satisfied with the organization and performance of the teaching the lab lessons with Arduino.	3.79	4.14
2. Learning resources and teacher feedback were available and useful for following lessons and completing assignments.	4.0	4.32
3. I am satisfied with my own progress in making Arduino projects.	3.48	4.29
4. I was able to solve hardware or software issues if they occurred.	2.93	3.92
5. Learning with Arduino was an interesting experience for me.	3.57	4.36
6. Lessons were of appropriate difficulty and I was able to follow them.	3.38	4.07
7. I am satisfied with the competences I have acquired in the lab lessons with Arduino.	3.52	4.25
8. I would recommend other students to participate in lab lessons with Arduino.	3.88	4.42
Total	*3.57*	*4.23*

It seems unexpected that students in online classes were more satisfied with their ability to solve hardware or software problems when they arose, but these students were not faced with a physical Arduino, which caused much frustration for the students. In online classes, each student worked individually on each Arduino project and had the opportunity to personalise their learning and experiment without fear of breaking anything. In blended learning, students worked in teams with a physical Arduino and had limited time to complete their projects, and the contribution of team members was often uneven. Consequently, in online learning students were more satisfied with their learning experience, their personal development and the skills they acquired. Both groups of students agree that they would recommend the lab lessons with Arduino to other students, although the students in the online learning agreed more with this statement.

Using the t-test for two independent samples, the observed differences in student satisfaction with teaching and learning using two different methods were found to be statistically significant. The students who learned completely online (*N=30; M=4.23*) showed significantly higher satisfaction with learning with Arduino compared to those in blended learning (*N=42; M=3.57*), which was confirmed by a t-test, $t(70)=3.91$, $p<0.01$. With a confidence level of 99%, the null hypothesis H0 can be rejected.

Since blended learning combines two approaches, on-site learning and online learning, it is expected that students are more satisfied with it. There are studies that confirm student satisfaction with blended learning. However, some recent studies report high satisfaction with online learning, which offers many advantages to students (Elshami et al., 2021). Online learning is also supported by studies on the use of Arduino in online laboratory activities in undergraduate physics, which show that students were more creative in designing and conducting experiments, discussed topics in more detail and thought more deeply about answers to questions, while grades did not differ from those in traditional learning (Organtini, Tufino, 2022).

Conclusion

The Arduino platform has great potential for use in education and prepares students for the dynamic job market in the IT sector. In both, blended learning and fully online learning with Arduino, students solve project tasks, gain insight into how real systems work and communicate with each other, and understand the applications of what they have learned. In blended learning, students learned a lot from each other by working in teams, sharing tasks and responsibilities, and solving problems through mutual communication, which gave them some new practical and social skills. At the same time, the physical connection of the electronic components to the Arduino board caused many problems for the students, which they faced for the first time, and caused a lot of dissatisfaction. Fully online learning during the period of global lockdown brought some advantages to the students. Learning was location-independent, students felt stress free and they showed more effort, motivation, and creativity. The Arduino simulator in the web-based software Tinkercad Circuits facilitates experiments with the Arduino and improves the overall learning experience for the students. Although the teacher needed more time to prepare the online lessons, give feedback and monitor the students' work, there was no need to check the correctness of the Arduino kits. It seems justified to use the Arduino simulator in on-site teaching to enhance the blended learning experience.

Scientific Ethics Declaration

The author declares that the scientific ethical and legal responsibility of this article published in EPESS journal belongs to the author.

Acknowledgements or Notes

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