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Physics – IT based international student exchange program

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Abstract. International student exchange programs are an integral part of the life of high school students across Europe. The popularity of these programs is understandable because the participating students can not only learn foreign languages, but they can also learn new cultures and make friends. The motivating force of this popularity was used in our program to bring even those students closer to science and engineering, who perhaps would not ever get closer to these areas. In our paper, we present a “project week” alike event, in which we used a simple, manageable, affordable and programmable electronic kit – Arduino – for the development of relevant competencies of our students and for the knowledge of physics and information technology.

1. The Electronic system and pedagogical basics

1.1 Short presentation of the Arduino

Arduino is an easy to use, open source electronic development platform that was born in 2005 [1]. The basis of this platform is a very simple programmable open source microcontroller that can be used to control other electronic devices. Not only the source code is open, but the hardware is also "free", so the wiring diagrams for Arduino boards are also freely available on the Internet [2]. The biggest benefit of the system is that both hardware management and software backgrounds can be easily handled without major preliminary knowledge.

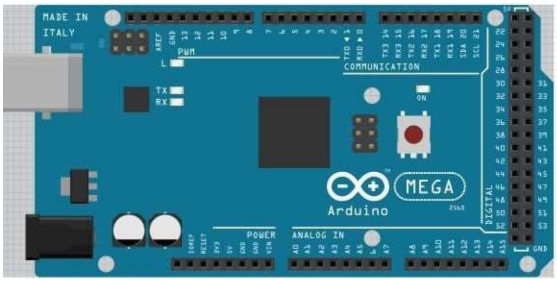

Figure 1. Arduino Mega board.

Software libraries created by developers and users are in huge quantities available to any user. The benefits listed above, and its affordability make it possible to use the system even in public education institutions. The main software for Arduino can be downloaded from the website: https://www.arduino.cc/en/Main/Software

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1.2 Pedagogical basics

To develop students' knowledge in sciences, IT skills and other competencies, we have chosen the project method as the basis for our pedagogical and didactical work. In a "project", according to the interest of the students, an interdisciplinary problem of real life is processed, together with the collaborative work and own responsibility of students, to create a product that can be used in real life.

According to researches six 21st century skills have been identified: 1. collaboration, 2. knowledge construction, 3. self-regulation, 4. real-world problem-solving and innovation, 5. use of ICT for learning, and 6. skilled communication [3]. We have built our project based on the above-mentioned principles to improve the participants the most efficiently: our students were working in German-Hungarian pairs on ICT devices, with clear daily goals and chance for creative tasks.

2. The project

2.1 Introduction of the exchange program

The project was first realized in 2016 with fourteen 8th grade students of the Georg-Cantor-Gymnasium (GCG) in Halle, Germany and fifteen 9th grade students of the Deutsches Nationalitätengymnasium (DNG) in Budapest, Hungary. The positive experiences of our first project prompted us to consider and develop the program more seriously. The project to be presented here was held in June 2017. Of the weeklong exchange program, three days was spent studying Arduino and implementing project tasks. In the following we present our work, which is a suitable project for a project week in any high school.

The GCG is a STEM school. Among other things, thanks to the character of the GCG, our German students had a relatively high experience in scientific projects. Our colleagues in the GCG are Anett Tuppack and Tony Stein mathematics, physics and IT teachers, leaders of the mechatronics lessons in their school. The Hungarian school (DNG) is rather humanities oriented, so most of the students have no deeper experience in scientific projects and their knowledge in STEM subjects is also lower as the GCG students'. According to the established conventionalism, during the exchange program the host party organizes the program for the students. In this article, we present the program of the Hungarian part of the exchange program with special regard to the "professional" part of the program.

Figure 2. Final product (Arduino-controlled vehicle) and the producer German-Hungarian team.

During the project, students spent three days, about four hours a day using Arduino. On these days, classes were held in the morning, and after a common lunch various programs were waiting for the students (labor visit to the ELTE University, city quiz in the Buda Castle, boat trip on the Danube and visit to Parliament).

The main task of the project for the students was to create an Arduino controlled vehicle until the last session, which, when it detects a wall, will stop and emits either a light or sound signal. Since the background knowledge of the Hungarian students in circuit building and programming was very small, this is a very ambitious goal in such a short time.

To reach this ambitious goal, we had to make every minute of the project as effective as possible. Beside this essential effectivity we had to keep in mind the skills we wanted to develop beside the physical and programming knowledges. Based on this, the lessons of the project were built up as follows:

- Introduction of the project on the first day / Repetition on the second and third day (physical background, electronics, programming)
- Setting goals for the day
- Short frontal instruction about the physical background of the daily topic
- Construction and operation of daily basic circuit in pairs (with on-demand teacher assistance)
- Creative tasks in pairs based on previous knowledge.
- Daily summary / Presentation of the projects' results on the last day.

In the following subsections we present the details of the three working days of the project.

2.2 Day #1: Flashing LED

The aim of the first session was to complete the simplest task, the programming of the flashing LED. The first task must be quite simple to make sure that the students understand the basic ideas of the Arduino-system. Due to the short time, the physical basis of the LED's operation was discussed appropriate to the age and pre-knowledge of students. To make the explanations the most effective we used frontal methodology with using projected animations such as videos. During the lesson we focused on practical activities and understanding the basics of programming. The further part of the day's work was based on worksheet (and later the other ones too) consisted of two parts: In the first part, the basics were laid out in a recipe alike manner (in this case the flashing LED), while in the second part the pupils could read the additional (so called creative) task. The program code of the flashing LED can be red in Figure 3. (b). As it can be seen, the language of the Arduino is very practical and simple.

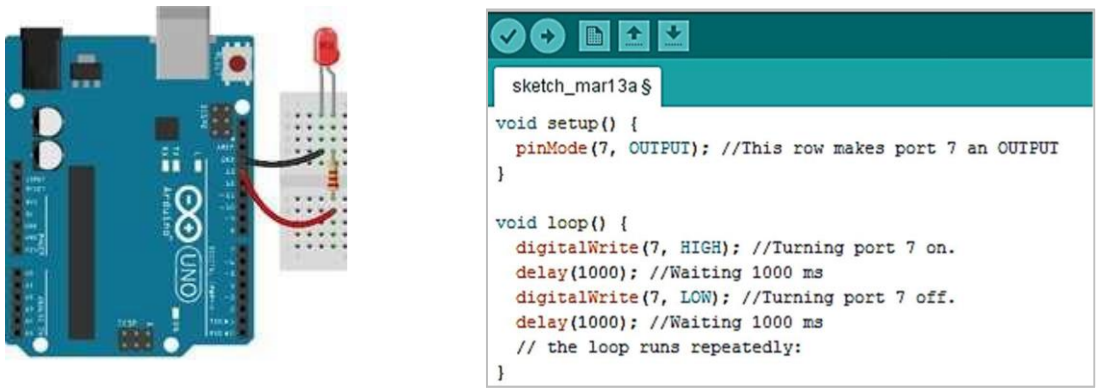

Figure 3. (a)The circuite of the first task (left) and (b) the programm code of the flashing LED with explanation after the „ // ” signs (right).

The creative task was to deepen the knowledge and to support the promotion of own ideas of the students. The first creative task was the compilation and programming of a traffic light model. Apart from the fact that the students have worked on a practical application, the understanding of the Arduino- system could be tested as well by this task. In the case of the traffic light, the first step that the students had to do independently was to connect three LEDs to three different ports and using „delays" in the appropriate sequence to simulate a real functioning traffic light. All of the pairs had their solution for this task too, some of them could even improve this model to a two traffic lights system.

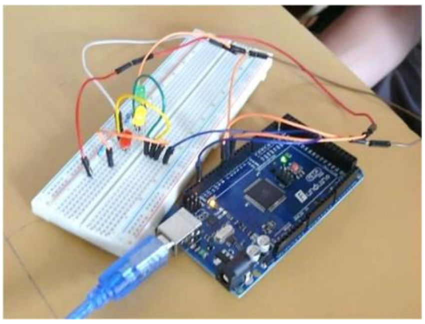

Figure 4. Simple traffic light modell

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2.3 Day #2: Distance measurement

One of the essential knowledge for building an intelligent car is distance measurement. Programming this was a big step for the students. The use of variables and the need for the use of the IF structure came together here. The use of variables proved to be more difficult. There were two major difficulties for the students here. First, it was a problem for many students to accept that letters or words could mark numerical values. Secondly, it was also a problem that most students identify *variable*-s in programming with unknowns from mathematical equations (see Fig. 5.). In this context, for our students it was difficult to understand, for example, the following:

$$variable = variable + 1;$$

```
void loop() {
 brightness = brightness + 1; //brightness increases in every round
 analogWrite(7, brightness);
 //setting "brightness" as the signal to the LED
```

Figure 5. The critical part in the code that continuously increases the brightness of a LED

```
sketch_mar13a §
digitalWrite(trigger, HIGH); //the bagin of the signal
delay(10); //the length of the signal is 10 ms
digitalWrite(trigger, LOW); //the end of the signal
timeinterval = pulseIn(echo, HIGH); //measuring the return time
distance = (timeinterval/2) * 0.03432; //calculating distance
if (distance >= 500 || distance <= 0) //logical examination, || means "or"
{
Serial.println("No data");
//if the condition is satisfied printing "No data" on the screen
}
else
{
Serial.print(distance); //printing the distance
Serial.println(" cm");
}
```

Figure 6. Part of the code of the distance meter program

It is easy to see that the application of the programming code used to calculate the distance was difficult for students in many aspects. On the one hand, it was necessary to accept the use of *variable*-s in programming and, on the other hand, the conversion between units – because the time is measured in milliseconds, while the distance is finally obtained in centimeters.

2.4 Day #3.: Transistor

On the third day the students task was to control a DC-motor from code. From electronical aspect this was the most difficult problem in the project. We explained the operating principle of the transistor just with illustrative images, due to the shortness of time. Fortunately, the code of the basic motor-controlling (two seconds running, then two seconds stopped engine) is the same then the programming of the blinking LED, so it seemed to be easy to the students.

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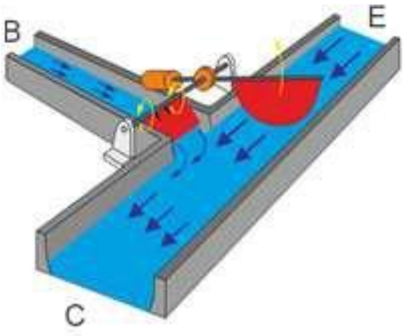
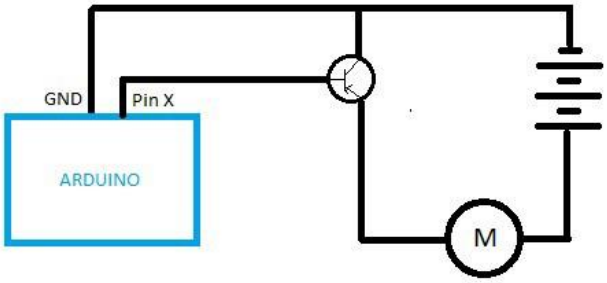


(a)



(b)

Figure 7. (a) The illustration of the working principle of the transistor [4], (b) quote from the engine control task bar.

Even though the students got a clear wiring diagram, according to our test results only seven of the 29 students could reproduce it correctly, and only six of them could shortly summarize the role of the transistor. The improvement of this result is necessary for future projects.

2.5 The final step: „autonomous" car

The final step was the compilation of the individual parts, and the coordinated programming of them. The fact, that it was done by all of the students with more or less help, is a great performance. Figure 8 shows the wiring of the cars which was built by all the student groups. The programming of the cars was problem free for the most pairs. The main difficulty for the majority of students was the usage of the if condition.

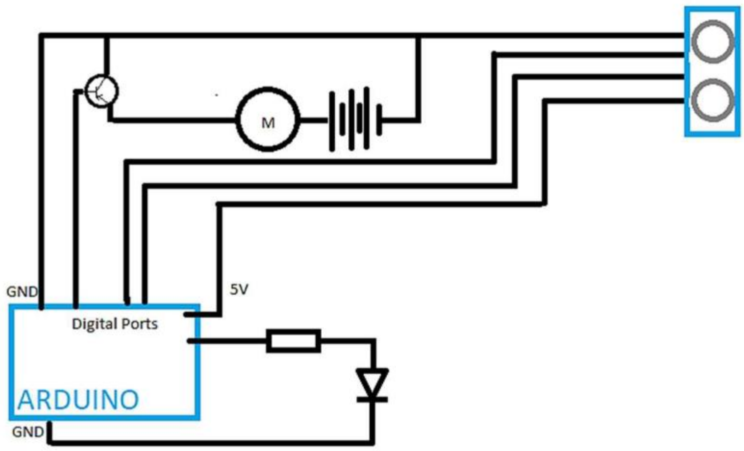


Figure 8. The wireing diagram of the project cars

The pairs who were faster with the tasks had the chance to try a more difficult task. With the H-bridge the direction of rotation of the motors can be varied, so it is possible that the car does not just stop at the wall, but also turn away. This was only achieved by a relatively small number of pairs until the end of the project, but this is not a problem, as this is only an optional and challenging task for the enthusiastic students.

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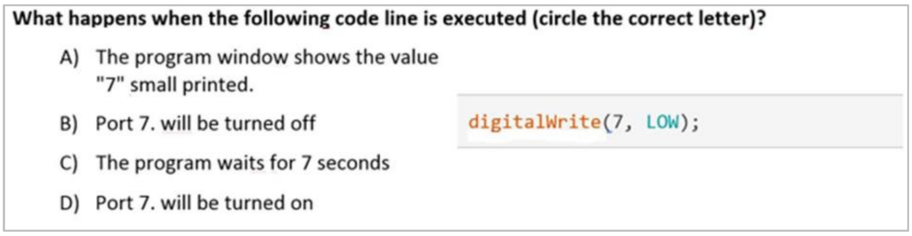
Figure 9. Building the cars.

3. Testing

During our project we used pre-post testing. The pre test was completed before the first session, the post test was completed after the last session, to measure the value-added due to the project. The performance of the students was measured at four levels of knowledge, namely recognition, naming, reproduction, and application. The tests contained 10-12 questions on the assessment of physical and programming knowledge based on the four levels of knowledge we explained above.

The first question (Figure 10.) was to assess the knowledge level of recognition of programming basics. Figure 11. (a) and (b) show different levels of questions. In the first case, the task of the student is to recognize and select the correct figure from the existing options, which task fits well with the level of recognition. The question of Figure 11. (b) „What do you see on the picture" is classified into the naming level, since besides recognition, the task of the student is to recall the name of the device.

The third question to be presented (Figure 12.) belongs to the level of reproduction, since this switch had to be used by students when preparing their cars. The question is also a good example of how small details should be considered when specifying test questions. The battery for the motor power supply is not explicitly present. In our experience it was very confusing for the students to solve the test.

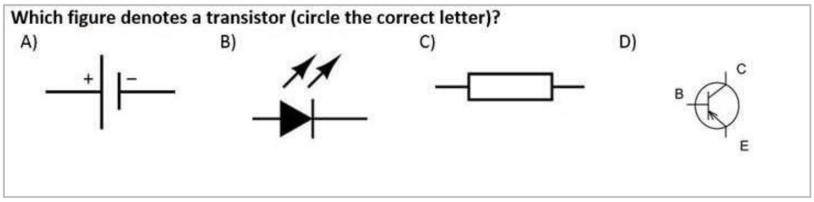


What happens when the following code line is executed (circle the correct letter)?

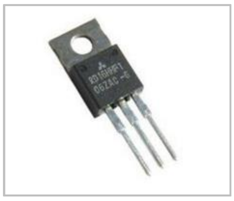
A) The program window shows the value "7" small printed.
B) Port 7. will be turned off
C) The program waits for 7 seconds
D) Port 7. will be turned on

```
digitalWrite(7, LOW);
```

Figure 10. Post test question. Topic: Programing, Level: Recognition



(a)



(b)

Figure 11. (a) Pre test question, Topic: Basic knowledge of electronics, Level: Recognition (b) Pre test question, Topic: Basic knowledge of electronics, Level: Naming.

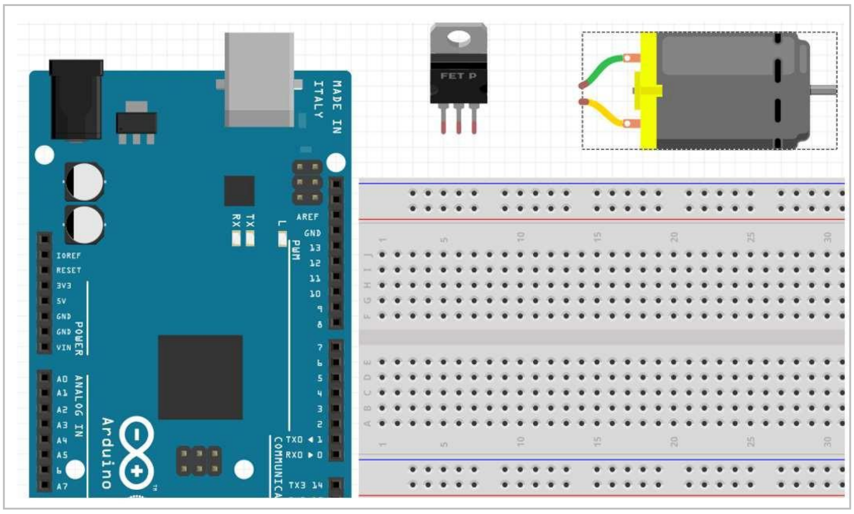


Figure 12. Post test question, Topic: Basic knowledge of electronics, Level: Reproduktion.

Answering the questions about the applications meant the most difficult work. A good example of this is a programming task, in which students had to code to flash a LED on a port which was not used before. The question is whether it is about to use knowledge or just reproduction. This is questionable because we have programmed flashing LEDs during the project only with different circuits. So, the task of the students was to replace the correct port numbers in the already known program code, but to do so, they had to understand the operation of the code lines.

4. Results

As the above-mentioned problems highlight, the test method did not work perfectly during the project yet. The pre and post tests were completed by 29 students. In both countries, we created two control groups for the same age but not participating in the project. The fact that the GCG is a STEM school is clear to see in the pre-test results. The results of our groups are shown in the Figure 13.

Due to the limitations of the article, we can say without any detailed data, it can be seen from the results obtained from the examination of the knowledge levels, that we have achieved progress in almost all the tested knowledge levels. However, development at the higher levels is smaller. It is therefore advisable to include more tasks in the project that develops those levels. For reliable presentation of the results, our data were subjected to statistical analysis. Its main achievements are:

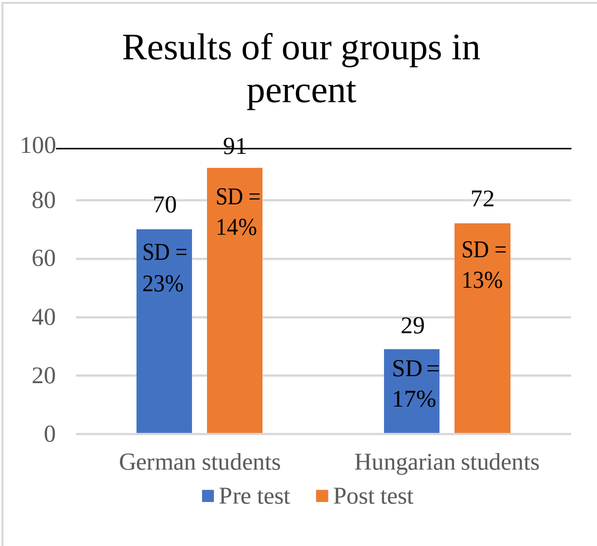


Figure 13. Average percentages of the groups and their standard deviation for each test.

- There was no significant difference between the results of the Hungarian experimental and control group ($p = 0.156$ where SPSS signifies the significance level). That means, that the Hungarian students are average in their school.

- There was a significant difference between the German experimental and control group ($p < 0.01$) and the experimental group performed better. This result can be explained by the different curriculum of the German experimental and control group. This carries the important information that the performance of the German experimental group cannot be inferred to the other students of their school.
- In the performance of the German and Hungarian experimental groups in the pre-test, there was a significant difference ($p < 0.01$) in favor of the German group. This is understandable, since the members of the German group – in contrast to the Hungarians - have been working with similar systems for a year now in a compulsory elective course within a robotics school course.
- For both nations, post-test performance is significantly better than in the pre-test (Hungarian: $p < 0.01$ German: $t(26) = -2.760$ $p = 0.010$ - in the case of the German group the distribution of the results is normal, so we could use t-test). This in our understanding means that we have effectively passed on both physical and programming knowledge for both nations.

5. Conclusion

During the three days of the project we gave students the opportunity to expand their knowledge and to apply them in practice, just as in the development of 21st century soft skills. Our program, in addition to programming knowledge, has strengthened the physics knowledge of our students: such as better understanding of electrical circuits, sound and ultrasound properties, basics of the semiconductors and their applications, and the mathematical modelling of physical phenomena. Of course, the actual topic of the here presented project can be freely changed to any specific groups, thereby also the aim on physics of the project can be freely changed.

The interpretation of the results is very difficult due to the problems and deficiencies listed in the description of the test. It is a pleasure to note that both groups were able to achieve a significant difference between the pre and the post tests, which we interpret as being able to improve the students' knowledge. Although the Hungarian group developed better than the German, it was not enough to overcome the initial difference.

Test results are not the only indicators of the success of the project. Perhaps, it is even more important, that we have been able to make physics and engineering interesting for our students in such a short period of time, with the use of an affordable system. The best indicator for this is that almost all our students working on Arduino have come to our Arduino course started in September 2017.

In addition, the differences between the two countries and the two different types of schools draw attention to the important fact that our students may be very different. With this in mind, it is worthwhile to refine and shape the project we have presented for each group, based on its individual characteristics. In this way, we hope that the interest of many students with a colorful composition can be turned towards science and information technology.

References

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[2] Internet: http://www.itkommando.hu/site/arduino-attekintes/ (last test: 30.03.2018.)
[3] ITL Research: 21CLD Learning Activity Rubrics
[4] Internet: https://www.leifiphysik.de/elektronik/transistor (last test: 30.03.2018.)