Erasmus+

STEM

Advancing STEM Education **with IoT Experiments**

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Introduction

Introduction

This publication was developed in the framework of a project [Advancing STEM Education with IoT Experiments] co-funded by the Erasmus+ programme. The key issue that we addressed in the project is how to utilise the potential of the Internet of Things (IoT) in school teaching of STEM subjects.

The Internet of Things is one of today's technologies that rapidly change the world in which we live: smart cars, smart homes, and smart cities are redefining our lifestyles. IoT is a particular field in which STEM knowledge is required to solve problems in a holistic fashion, thus providing excellent content for active problem-based learning, e.g., engaging students to design solutions for monitoring climatic conditions in the classroom or waste management system for the school. In such cases students learn a specific topic across a range of disciplines through practical hands-on tasks.

Teaching STEM in an era of rapid technological advancements is a demanding task. Multiple studies indicate that schools have to address a number of challenges to offer up-to-date and engaging STEM education:

- Make it more interesting, relevant and motivating for students
- Progress from abstract teaching of these subjects towards project-based learning introducing new technologies
- Create learning environments where students can experiment with such technologies under the guidance of competent teachers
- Follow cross-curricular approach connecting subjects that are closely related but in actual practice usually taught in a disconnected way

The above challenges are particularly visible in secondary and high schools, the levels where students are expected to learn STEM subjects in more depth. To better understand the current teaching practice at these levels we conducted a survey in Poland and Portugal among high school teachers of the related subjects. Majority of the respondents were familiar with the concept of integrated STEM education but they mentioned a number of factors that make it difficult to implement the approach in their teaching. We summarise here the responses of those who either find cross-curricular STEM impossible to implement or hesitated if they are able to do it (listed from most to less common):

- Difficulty in connecting different subjects in actual teaching
- Emphasis on standardised test scores in teaching
- Insufficient time
- Not sure what projects to implement
- Lack of support
- Lack of tech resources in schools
- Unfamiliar with some technologies

Nevertheless, the majority of the surveyed teachers expressed a wish to get acquainted with new problem-based learning scenarios for school STEM projects.

We then researched the situation in other countries renowned for technological advancements in school education. In this process we discovered a network of Estonian schools that had already experimented with IoT for STEM https://www.exu.tlu.ee/rnd-smart-school. The direct contact with the key researcher from Tallinn University who coordinated this nation-wide project helped us choose one Estonian school who agreed to join our initiative and share their experiences from IoT workshops.

Comparing the findings from Poland and Portugal, on the one side, and Estonia on the other (based on evidence published by the researchers from Tallinn University) we concluded that the main barrier towards large-scale implementation of STEM education lies mainly in strict curricular frameworks which give teachers little space and time to go beyond the borders of their predefined programme. Nevertheless, such an opportunity arises in additional workshops organised in schools as various enrichment activities. We thus decided to organise workshops to advance STEM education in our schools and then share experiences from these activities to influence teachers in others, particularly those where such an approach is novel.

The project that generated results that we are presenting in this publication involves schools from Estonia, Poland and Portugal with various levels of experience in cross-curricular STEM. It has an important transnational dimension as we have shared teaching approaches across different education systems. Such an opportunity is an essential driver of innovation as it lets all the participants examine and reconsider their standard, well established practices from a new perspective.

This publication includes learning scenarios that were developed for IoT workshops and then validated in the course of their implementation in our schools. It is addressed to science teachers and trainers working in schools or non-formal education organisations open to innovation in their teaching practice, particularly those who seek new opportunities to extend or improve their programmes in the field of STEM.

The project partners cooperated closely in the process of writing the publication. In each country we developed different learning scenarios in different STEM areas. Transnational cooperation gave us a unique opportunity to gain insights into educational contexts which would be otherwise inaccessible due to language barrier and lack of access to other educational environments in foreign countries. In what follows we share the results of this cooperation. Three public schools and one informal learning provider contributed input to the publication.

Education Centre EST - Wadowice, Poland (project coordinator)

EST is a lifelong learning centre offering educational programmes to young people in a range of disciplines and adults upgrading their qualifications.

The courses offered to school students from across the region include foreign language courses, computer workshops and arts/artisan classes, some connected with entrepreneurship initiatives. Hundreds of young people participated in our programmes; an average number per semester approximates 150. Adult participants include school teachers who have attended our regular courses (e.g. English certificate courses), participated in one-off initiatives organised by us (conferences, seminars, trainings) and European mobility events (meetings in other countries, exchanges).

In 2003 we developed our first EU project in the field of digital media communication which opened a new field of European cooperation. Since then we have participated in many European initiatives spanning the fields of adult education, vocational training and youth work. As a result, the courses offered by us have gained additional value through exchange of approaches with other organisations in Europe and an essential intercultural dimension. At present our priority lies in the field of digital creativity: game making, coding, 3D design and prototyping, robotics and drone construction.

The following members of our team were involved in the development of the publication:

- Aleksander Schejbal, coordinator of the project and editor of the publication
- Łukasz Putyra, digital skills trainer, designer of the publication layout

The Centre for Vocational and Continuing Education No. 2 - Wadowice, Poland

The Centre was established in March 2017 as a result of integration of two vocational schools and as such is the heir to the long tradition of the two schools and a rich offer of vocational and general education, meeting expectations of employers who need well-educated, qualified and specialist staff.

The current number of students approximates 1100 in 38 branches (in szkoła branżowa, technikum, liceum). The Centre has 130 employees.

On the basis of the knowledge and experience of its educators, the Centre aims to:

- educate young people and adults
- provide vocational counselling and career guidance
- cooperate with employers and employers' organisations
- take care of comprehensive development of the student
- support the educational role of the family
- implement preventive programmes

In the ranking of high and technical schools conducted by the Perspektywy 2018 magazine, we are in first place in the Wadowice District (powiat), in the 7th in the Małopolska region and in the 40th in Poland.

Our Centre is a safe and student-friendly school, which reliably and competently prepares its students for future careers, in an atmosphere of mutual kindness and integration, according to the modern requirements and expectations of the labour market. The school gives real opportunities for interesting learning - supported by apprenticeships and internships - and finding a job after its completion. Keeping pace with technological developments, we use the latest technology and multimedia programs in the education of our students, including interactive whiteboards and elearning tools.

We cooperate with local employers and institutions with a significant impact on the local labour market, including the Craftsmen's Guild and Chamber of Commerce in the organisation of student internships, practical workshops and career counselling. We are also active in the local community, cooperating with other organisations operating in the region of Wadowice. We also receive substantial support from local authorities. For example, the District (Powiat) runs a project - Wadowice Centre for Vocational and Continuing Education - with funding for retrofitting the school, internships and teacher training.

Teachers involved in the development of the publication:

- Dorota Szemik, vocational counsellor and the school's vice-director
- Jarosław Zieliński, IT teacher
- Damian Basiura, IT teacher

Jorge Augusto Correia School - Tavira, Portugal

Dr. Jorge Augusto Correia is a vertical grouping of schools from preschool through high school located in Tavira.

The School Group has about 200 professionals operating day and night, including the support staff and the professionals accountable for the educational and training offers. The students come from very diverse social backgrounds and live in urban, fishing and rural areas. Additionally, approximately 10% of our students are from foreign families. We are a public entity that works based on Knowledge and is supported and based on Values to promote the individual and social development of our 1808 students by promoting vocational courses and fostering additional educational programmes.

Children with disabilities, special needs or learning difficulties mingle with mainstream students, for our School Grouping strives for an inclusive education. It is the only high school in the municipality of Tavira, attended also by students over 18 in evening classes.

From 10th to 12th grade, students choose one field of study: Science and Technologies, Social and Economical Sciences, Languages and Humanities and Visual Arts. In the vocational area, students may enrol in IT Systems and Programming, Sports, Tourism, Civil Protection Services, Educational Technician, and Trade Technician.

The School Group provides different types of Educational Support, namely: pedagogical support, tutorials, Learning Support Centre, School Libraries, Psychology and Guidance Service, Students Office, Clubs and projects, Health Education, National Reading Plan, School Sports, Eco-Schools, Youth Cinema School, and Erasmus+ Projects.

Several institutions actively participate with the school to provide the best education and specialised knowledge to our students, including Centro Ciência Viva (Interactive Science Centre), Algarve University, local Police and Firemen, nurses and doctors from the Health Centre, among others.

The school building is approximately 40 years old, so thermal insulation is not efficient for average temperatures in Tavira. Therefore, contextualising this project in the characteristics of Tavira's climate and in the type of classrooms of our High School building, we proposed monitoring the temperature and CO_2 levels in the classrooms and addressing other everyday life situations that affect our community.

Teachers involved in the development of the publication:

- Cristina Castilho, physics and chemistry teacher
- Anabela Silva, physics and chemistry teacher
- Telma Costa, maths teacher
- Cláudia Rosa, maths teacher
- Conceição Santos, IT teacher
- Hugo Pereira, IT teacher
- José Afonso, electricity, electronics, automation teacher

Valga Gymnasium - Valga, Estonia

The Gymnasium is a state upper-secondary school that can be considered a Mecca of education in the area. Our school has been organising workshops for all the schools in the county for years. The workshops, and everything that is done and created there have always reflected upon the mentality of Valga Gymnasium, and involved the specificity of every field of study. In our school, it is possible to choose between four different fields of study: humanities, science, economics, and national defence. As being a part of UNESCO Associated Schools Project network, and working on the principles of Mondo world school, it is our duty to offer our students the best choice and perspective for their future in this contemporary fast-changing society.

Valga Gymnasium has about 177 students in three years (10th- 12th grade) and 25 teachers. The schoolhouse is a recently renovated building with new furniture and equipment. Valga Gymnasium has just celebrated its 100 birthday.

The rapidly developing technological landscape challenges educational institutions to constantly renew the school's digital infrastructure in order to keep students engaged in learning difficult subjects such as Science, Technology, Engineering, and Mathematics (STEM). The Internet of Things (IoT) is one of such new technology platforms that could help the schools enhance learning processes with innovative resources, and to increase students' motivation to learn.

The Gymnasium participated in a nationwide project "Innovatorium – Smart School through the Internet of Things". In this project, every school got a smart gear case – consisting of smart clothes, room sensors, digital art, science laboratory and body censors – to try them out and create study materials. Thus, we have tried them out in different lessons over one year. With this project, our school won the annual prize of educational technology addressing the following aims:

- Increase the students' interest in technology and engineering
- Guide the learners to solve vital problems in their surrounding environments
- Change the natural and exact science's curriculum in schools to be more innovative
- Contribute to the effectiveness of lifelong-learning
- Create opportunities for engineering creativity

In addition, one of the goals is to support the cooperation and sharing of knowledge and experiences of STEAM education teachers. The project contributed to developing the digital competencies of teachers and learners using IoT technologies, while integrating different subjects to better their analytical skills, i.e., analysing the results of activities using different software.

Teachers involved in the development of the publication:

- Pille Olesk, the school project and career manager
- Meelis Oja, ICT manager
- Virgo Park, IT teacher

Chapter I

IoT for STEM education

Chapter I: IoT for STEM education

There is a wealth of evidence on the value of experiential learning of science subjects in direct relation to technologies that rapidly transform the world in which we live. The potential of IoT that facilitates such learning has not been fully discovered in schools. Indeed, the majority of STEM teachers that we surveyed are new to the idea. In this introductory chapter we therefore propose to address this knowledge gap and outline the following topics:

- The concept of IoT and how it has revolutionised the way we organise living environments
- Exemplary IoT applications in education that facilitate STEM learning in schools
- Some of the requirements that have to be met in order to conduct IoT experiments with students in terms of the pedagogy and affordable technologies

The concept of IoT

IoT is one of the emerging phenomena today. New technologies make it possible to connect almost any physical device to the Internet, which makes it possible to remotely control them and work with their data. Most of these devices are capable of mutual communication and can be directly integrated into the Internet. This is the source of the concept of the Internet-of-Things (IoT). By the term we understand a set of interconnected devices and objects that collect, exchange and employ information through the embedded electronic systems.

The idea of interconnected remote devices for increasing safety and improvement of system operations dates back to the 1950s, when first applications of interconnected sensor systems (Wireless Sensor Networks) were initiated. Next, sensor systems were developed to activate various objects being monitored/detected (Wireless Networks of Sensors and Actuators). And finally, the systems grew into networks of objects capable of mutual communication. These interconnected systems are named IoT.

Nowadays, the development of IoT systems relates to the advances in the production of microelectronic systems that enable the powerful data processing system integration in a single circuit, advances in the field of sensors, in communication technologies and in the processing and analysing of large data (Big Data, Data Mining).

As a result of these advances, IoT is touching almost any kind of our daily activities:

- Automation of households and buildings
- Intelligent cities
- Intelligent factories
- Automotive industry, transport
- Wearable electronics
- Healthcare
- Precise agriculture
- Fun electronics
- Military applications and many more

With such rapid and widespread IoT developments, it is necessary not only to talk about the IoT revolution, but also to directly introduce the related technologies in the science lessons in schools.

IoT applications in school education that facilitate STEM learning

Despite the fact that the importance of IoT is widely acknowledged among STEM teachers, there are very few well documented cases of its applications in school education. In what follows we would like to summarise three such cases from very different educational contexts before we proceed to a more detailed presentation of our own learning scenarios in Chapter II.

Designing IoT applications for a Smart City

We would like to begin with a brief presentation of a case of introducing IoT to lower secondary students with the use of only basic, freely accessible resources. This approach was successfully tested in the framework of a Horizon2020 research and innovation project, UMI-Si-Ed, with a class of Norwegian students aged 14 - 15, both boys and girls.

The main question examined in this intervention was the following: how can a design methodology be used as a means to educate young students who are not familiarised with IoT? The question was prompted by a recognition that designing IoT solutions cultivates 21st-century skills and can help towards making the symbolic and abstract manipulations involved in IoT design more concrete and manageable for young people. This was seen as an important step forward in view of the fact that most of the design methods found in the IoT literature target the end users of the IoT applications rather than students, and as such they don't pursue educational goals, especially for lower grade school students. The importance of this project approach is further supported by a growing need to empower digital citizens acting as designers of IoT applications, the goal which can be addressed by STEM workshops in schools.

The UMI-Si-Ed workshops focused on designing solutions for a smart sustainable city, a concept growing in popularity due to its potential various benefits: environmental, physical, social, and economic (e.g. more efficient traffic flow, better management of public buildings, reducing the costs of public lighting, better managing waste removal, more effective policing and emergency services, etc.). The workshops consisted of three main phases:

- Introduction to IoT as one of the most important topics in ICT today and its various applications that span a wide range of domains, including home, cities, and the environment.
- Design challenge, during which the students worked collaboratively in small groups to create an IoT-infused design solution and present their ideas to their peers and the facilitators.
- Student assessment via answering a quiz with some game-based elements which allowed the facilitators to gather instant feedback on the proposed activities.

During the main design part of the workshops the students were using a Tiles IoT Inventor Toolkit as a card-based brainstorming tool to generate ideas for IoT products. Tiles is an educational activity resource helping to learn about design and IoT technology by ideating concrete solutions. It includes over 100 brainstorming cards that provide a resource for a game-based learning experience engaging students in various design thinking activities with tools for scaffolding the process, either as an individual activity or team-based during in-person or virtual workshops and hackathons.

During the workshops, the students were working in groups of four or five persons. They expressed their ideas both in a written form using a dedicated space in the Tiles Toolkit Board, but they also had the opportunity to pitch their ideas at the end of each session. A number of different solutions for a smart city were developed and presented by the students as results of the workshops:

- Smart waste management: the students came up with an innovative and environmentally friendly solution of a smart public bin for waste reduction.
- Smart transportation: this idea involved a smart transportation subsystem to enhance the driving experience for the bus driver with a range of services (traffic monitoring, maps, public web camera, weather forecast)
- Smart bus stop: providing instant access to various information and media in an electronic format, e.g. news, relevant warnings, persons proximity, etc.
- Smart wheel chair: enhancing elderlies' mobility within a smart city; e.g. the wheelchair has built-in sensors and services (like GPS and maps) to calculate the route based on real-time traffic data and thus helping disabled elderly people to make it on-time to their appointments.

As regards the evaluation results, the students perceived the workshop as a joyful experience advancing smart city learning, helping them to think about different aspects of the problem and different possible IoT solutions. The feedback gathered from the students indicate that they would like to take further their ideas and create physical prototypes of the designed solutions. This was however beyond the scope of the planned workshop activities.

Smart Schoolhouse by Means of IoT

Tallinn University provided know-how to 19 Estonian schools on the implementation of sensor sets for turning their “dumb” school house into a smart one. Using these sets in teaching and learning had an objective to raise students’ interest towards technology, related knowledge and solving real life problems, thus making learning STEM subjects more engaging and down-to-earth.

The main goals of the 3-year project were to:

- Increase the students' interest in technology and engineering
- Guide the learners to solve vital problems in their surrounding environments
- Change the natural and exact science's curriculum in schools to be more innovative
- Contribute to the effectiveness of lifelong-learning
- Create opportunities for fostering creativity
- Support the cooperation and sharing of knowledge and experiences of STEAM education teachers

In order to achieve the project’s goals one of the most important steps was procuring IoT devices for which an indepth research was conducted. After a series of teacher interviews and focus groups, the required devices were obtained that allowed students from the participating schools to design and construct various IoT applications with the following sensors:

- Room sensors: Proximity Beacons, Xiaomi Mijia 6 in 1 Smart Home Security Kit, 45 different sensors-temperature, humidity, capacity, six axis sensor accelerometer, gyroscope, 3-axis gyroscope, 3-axis accelerometer, IR motion sensors etc. LED Kit, Raspberry Pi 3 Sets, Z-Wave.Me RaZberry2, and accessories
- Smart clothes sensors: Wearable electronic platforms Flora and Gemma, Bluefruit LE Module, NeoPixels, Force-Sensitive Resistor, UV Index, Light, Accelerometer/Compass, GPS, temperature, Flex Sensor, Conductive Thread, Knit Conductive Fabric
- Research labs sensors: Teslong Portable Waterproof USB Microscope with 10-200 Magnification camera for Android, Mac and Windows PC, Open Garden Indoor Hydroponics kit from Libelium, Ozobot Bit Coding Robot, and PocketLab Voyager
- Body-sensors: NeuroSky MindWave EEG Headset, MySignals SW Complete Kit
- Digital art: Action camera Samsung Gear 360°, 3D printer Prusa i3 MK2S, Photo Studio set with Continuous Lighting Softboxes, Daylight Sets and Tripods, Google Home Speaker, SmartPhone Galaxy 6, Wacom Intuos Pro Small Graphics Tablet, and VR virtual reality Headset.

The schools were given three months to test these kits in the study process, after which, a meeting between the teams took place. During this meeting, the groups presented the positive and negative aspects of the kits they used, and during an interview with the focus group consisting mainly of half-structured questions, additions and corrections were made for the final procurement of the IoT kits.

The project contributed to developing digital competencies of teachers and learners using IoT technologies, while integrating different subjects to better their analytical skills, i.e., analysing the results of activities using different software.

Precision farming with IoT

The Computer Technology Institute (CTI), which is an institute supervised by the Greek Ministry of Education as the technological pillar supporting ICT in education designed and implemented online courses in the settings where there was a need to enrich the formal school programme with an introduction to IoT. The modular format of the online course, as well as the self-paced structure, made it ideal for students who wished to enhance their learning through extracurricular programmes. The course was implemented by the teachers collaborating with CTI in VET schools in Patra, Mesologgi and Argos. Also teachers from the Professional High School of Patras and Experimental High School of Laggouras implemented certain activities in class with their students.

The course on IoT in Agriculture and Precision Farming is based on the results of the project SKIFF: Skills for Future Farmers http://future-farmer.eu/. The flexibility of the produced material made it perfect for adaptation for VET schools with a view to acquainting students with the technology behind intelligent spaces and precision farming. The learning programmes focused on Arduino technology for introducing basic skills in handling microcontrollers used in various smart interactive devices as well as drones in agriculture.

Precision agriculture (PA) is an integrated information and agricultural management system that is based on several technical tools such as global positioning system, geographical information system and remote sensing. It is designed to increase whole farm production efficiency with low cost effect while avoiding the unwanted effects of chemical loading to the environment. The goal of precision farming is to gather and analyse information about the variability of soil and crop conditions in order to maximise the efficiency of crop inputs within small areas of the farm field. To meet this efficiency goal the variability within the field must be controllable.

Many sensors are currently available and used for data gathering or information provision as part of the PA implementation. Devices exist to assess the status of soils, to record weather information or micro-climate data, to quantify the physiological status of crops and they are based on remote sensing principles. Special interest is devoted lately to the use of low-cost light-weight unmanned aerial vehicles (UAV), commonly known as drones, enabling the generation of very-high resolution farm-level imagery.

Students who participated in the course were introduced to the integrated system of Precision Agriculture, which consists of 4 stages (Precision farming cycle).

- In the first step they learned the process of data collection that is used for elaboration of production maps, soil and other chemical analyses. During the cultivation period more data are gathered such as weather data, crop protection and seed treatment. Many of these processes can be automated through the use of appropriate IoT systems and sensors.
- In the second stage they focused on the analysis and elaboration of the collected data. The way in which data of each system is combined depends on the cultivation

and the algorithm that has been used. They learned to define and analyse management zones data within a parcel, which are characterised by common soil or agronomic and oenological characteristics.

- The third stage involved the implementation of field work and oenological interventions, according to the results of the previous stage. At this point the students learned to adapt the equipment that is used to support the application of variable crop needs in each of the field management zones.
- The fourth stage concerned the evaluation of the techniques applied which helps in the following crop year planning. The mapping of production and other parameters can be the starting point for the creation of management zones but also can be a point evaluation of the previous year.

An important part of the course was devoted to the use of drones in precision agriculture. The students learned how to identify different types of drones, their main parts, and some of the advantages of the use of drones vs manned vehicles vs satellites.

After the completion of the course the students were able to:

- Understand different implementations of Precision Agriculture (PA)
- Understand how data are collected for PA applications
- Examine the plant health in a crop field
- Measure some crop parameters
- Enumerate the benefits of smart farming

Prerequisites for IoT experiments in schools

At this stage it is worth considering some of the requirements that have to be met in order to conduct IoT experiments with students in terms of the pedagogy and affordable technologies. We would like to outline here some of the experiences and conclusions derived from the above projects as well as our observations from the workshops run in Estonia, Poland and Portugal.

STEM pedagogy

Teachers and their chosen pedagogies play a crucial role when it comes to arousing an interest of students in science subjects. There are a number of such pedagogies which are particularly relevant for STEM education. We identified the following ones which are especially important: experiential learning, problem-based learning (PBL), inquiry-based learning (IBL) and trialogical approach. All these methods help students get engaged in real research in the way scientists do, and help them build an understanding of science concepts.

- Experiential learning: this is an approach that helps involve students fully, openly and without bias in new experiences and thus help them develop concrete experience abilities. We mean here experiences that happen in the real, physical world. In the case of IoT workshops, concrete experiences result from collaborating on designing an IoT application for a given context and needs.

- Problem-based learning: this is a teaching method that makes students become the drivers of their education. It uses complex, real-world issues as the classroom's subject matter and encourages students to develop problem-solving skills as they learn concepts instead of just absorbing facts. For example, in the course of IoT workshops, students pitch their ideas and create a solution to an environmental problem (e.g. how to minimise energy consumption or limit carbon footprint).
- Inquiry-based learning: this approach encourages students to explore a topic on their own and learn from their first-hand experiences. It thus fosters their reflective observation abilities and abstract conceptualisation. In the course of searching for an IoT solution to a given issue the students have to think about ideas, techniques or approaches useful for their design solutions as well as reflect on and evaluate results of their experiments from different perspectives.
- Trialogical approach: this is a so-called knowledge-creation approach to learning based on activities in which students collaboratively develop new artefacts or products. The term 'trialogical' has the purpose to differentiate it from the 'monological' models of learning (processes of knowledge acquisition within the human mind) and from 'dialogical' models (emphasising social practices or interactions). In the trialogical approach, learning is enhanced through pedagogical arrangements and supporting technology. It results in concrete technological solutions designed, created and implemented by students, e.g. a CO2 classroom emission monitoring system with IoT devices.

IoT technologies for school education

In view of the challenges posed by rapid technological developments, schools need to constantly renew their digital infrastructure to ensure students' engagement in learning STEM subjects. One of these new technologies is the Internet of Things which provides an excellent platform for designing learning scenarios cutting across the curriculum of IT, Maths, Physics, Chemistry, possibly other school subjects (English, Environmental Education). In order to enhance students' motivation to learn with innovative IoT resources, teachers need to skillfully design workshop plans taking into account their curricular objectives, availability and cost of the equipment, as well as its re-usability for follow-up school STEM projects. This will certainly require preparatory design-based research focused on the choice of IoT devices suitable for use in the context of particular school workshops. In the following chapter presenting learning scenarios implemented in this project we briefly outline the technologies that the partner schools used for their workshops. In addition, in the closing chapter, we provide more details on where to look for specific items for implementing IoT projects with students.

At this point we would like to present a brief overview of three exemplary sets of resources, very well suited for school IoT projects.

Arduino

Arduino is an open-source electronics platform based on easy-to-use hardware and software. Arduino boards can read various inputs, e.g. light on a sensor or a finger on a button, and turn it into an output, e.g. activating a motor or turning on an LED. In order to tell the Arduino board what to do, you send a set of instructions to its microcontroller using the Arduino programming language and the Arduino Software (IDE). Arduino has been the brain of thousands of projects, from everyday objects to complex scientific instruments. It gathers a worldwide community of makers who contributed to a growing and accessible knowledge facilitating a wide range of STEM projects.

Arduino provides an Explore IoT Kit aimed at helping students get started with creating connected devices quickly and easily. With the Kit, they gain access to an integrated online platform, Arduino Create, that enables them to code, access content, configure boards, and share projects. The Kit also offers concrete activities needed to learn the basics of IoT, including: hardware, networking, algorithms and programming, security and data handling. The activities, based on a learning-by-doing approach, teach students how to collect and present data and how to use the provided devices and services safely and securely. With the Kit they can construct fully functional solutions, including experiments, challenges, and building meaningful applications. Each Arduino Explore IoT Kit serves up to two students and contains one Arduino MKR 1010 Board, one MKR IoT Carrier, a collection of sensors and actuators, access to an online platform guiding students through their first IoT experiments, specific online content for the teachers, as well as access to the Arduino Cloud to test all of the experiments.

Vernier Connections
It is a web-based platform created with a view to helping teachers engage students in interactive and relevant STEM investigations and projects. The platform provides educators from elementary school till college with data-collection technology and innovative experiments that facilitate scientific curiosity, understanding complex science concepts and concrete explorations.

In terms of the technology, Vernier offers a comprehensive set of resources for educational purposes:

- Lab equipment suitable for IoT experiments (e.g. solar energy exploration kit)
- Sensors (for measuring a wide range of parameters: air quality, temperature, gas pressure, light and colour, sound, etc.)
- Lab books with guided-inquiries, providing a stimulating structure to explore various scientific concepts
- Interfaces (e.g. LabQuest data-collection platform that students can use to collect and interact with data)
- Software for data analysis (e.g. graphical analysis apps for observing experiments, collaborating with their peers and sharing the results online)
- Packages for whole experiments (ranging from human physiology to climate and meteorology experiments)

In terms of concrete ideas for STEM workshops Vernier offers over 1,000 ready-to-use experiments that make implementing its technologies in the classroom/laboratory feasible. We only list here some of them relevant for IoT school projects:

- ❖ Studying Microclimates: In this investigation, students choose two unique locations and compare the weather at these two spots to the climate conditions in their area.
- ❖ Effect of air temperature on humidity: In this experiment, students use two temperature sensors to determine relative humidity at two different locations.
- ❖ Biofeedback: In this activity, students use a respiration belt and an EKG sensor, to monitor a subject's baseline physiological state and his or her response.
- ❖ Classroom Noise Monitor: The experiment requires students to collect data and make judgments about what level of noise is appropriate for the settings.

The above Vernier products are designed specifically for educational use. They are not appropriate for any other - industrial, medical, or commercial - applications.

Hardwario
Hardwario provides a comprehensive system of attractive STEM education for schools and hobby groups based on working with real IoT projects. The advantage of the system is that it offers not only technical resources but also detailed STEM lessons for hands-on learning of IoT. In cooperation with pedagogical experts from EDvisor Finland, they developed the lessons based on a research-based REALISE-EXPERIMENT-APPLY- REFLECT pedagogical framework. The framework facilitates the preparation, management and assessment of the lesson content. When it comes to implementation of this progrogramme of learning, the Hardwario IoT Kit comes as a useful resource for students to develop their IoT projects. Throughout the process they can count on technical and professional support of teachers in the form of detailed instructions, webinars, seminars and online chat.

The lessons deal with topics related to the school environment or current student interests and cover, inter alia: projects on indoor climate quality in the classroom, projects addressing environmental challenges such as climate change and/or waste management and projects related to student and teacher safety. The main target group is secondary school students although the resources can be used both with younger and older students depending on their interest in and ability to work with new technologies. The learning outcomes of the programme vary from the acquisition of general knowledge of IoT (concept of IoT, its benefits and risks, functions of concrete devices) to practical skills in assembling and programming simple IoT applications with the Hardwario IoT Kit.

Besides ready IoT kits there are more demanding possibilities to search and acquire individual components for IoT school projects. This is the way we followed in most of the learning scenarios that we present in the next chapter as an inspiration for other teachers to design and conduct their own IoT experiments with students.

Chapter II

Learning scenarios

Chapter II: Learning scenarios

This part of the publication draws conclusions from the preparatory research into IoT applications in STEM education, with some of its cases briefly outlined in the previous chapter, and presents a set of new original learning pathways for school students. By its very nature, the STEM approach advocates the design of learning activities in cooperation with teachers of different science subjects. We therefore built a group of chemistry, physics, maths and IT teachers to address specific educational settings and curricular standards in our schools, and elaborated a compendium of learning scenarios for the students. The composition of the partnership ensures the versatility of these contexts as our schools are different in terms of the specific teaching practice and available education technologies. Still the curricula are comparable and we identified standards in the subjects that we teach which are the same or very similar.

The following scenarios show different learning pathways that cut across the STEM curriculum. Their implementation was facilitated by cooperation with external institutions: the Tallinn University in Estonia, a science centre in Portugal and a tech company in Poland. Although the workshop plans originated in our particular educational contexts, we believe that they can be adapted and implemented in other settings where teachers face similar challenges and search for new ways to propose engaging learning experiences for their students in the field of new technologies.

1. Controlling a Heating System via the Internet from Android/iOS App and PC

This scenario comprises a series of workshops for high school students on designing and managing a 'smart' heating system. The programme was developed and implemented by the two Polish partner organisations in the IoT project, EST and CKZU, as an extracurricular learning programme bridging a number of STEM subjects. The students were introduced to the relevant technologies and challenged with a task to design an 'intelligent' heating installation for an old building of their school.

Relation to high school curriculum

Maths: reason quantitatively and use units to solve problems; perform arithmetic operations; reason abstractly and quantitatively; summarise, represent, and interpret data on a measurement variable; make inferences and justify conclusions from sample experiments and observational studies

Physics: design and perform experiments; value inquiry as the fundamental scientific process; identify variables and describe relationships between them; plan procedures to collect data on variables and control them; understand how more advanced electrical and electronic systems can be used in circuits with heat; design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering

Information Technology: develop and apply their analytic, problem-solving, design, and computational thinking skills; use technology purposefully to create, organise, store, manipulate and retrieve digital content; understand what algorithms are, how they are implemented as programs on digital devices; design functional products using digital tools; apply computing and use electronics to embed intelligence in products that respond to inputs and control outputs

Grade Level: 9th - 12th

Estimated time: developed as a 4-session workshop (can be shortened or extended)

Materials & Technology

- Computer lab with at least 1 PC for a pair of students
- Wireless temperature sensors
- Wireless temperature controllers
- Control device cooperating with a Wi-Fi module that allows you to change temperature in each heating zone
- Executive devices: radiator actuators
- IoT platform for wireless management of a heating system
- Smartphones with relevant IoT apps installed

The workshops were facilitated by a close cooperation with a local company Tech Sterowniki, a major producer of controllers for intelligent heating systems. They helped us organise the practical activities for our students, offering a workshop lab, materials and a support trainer. In what follows we present the learning scenario divided into four workshops as it was actually implemented by us. We used concrete materials and tools provided by the host company which can be learned in more detail through the links given throughout the text. However, the same or similar activities can be conducted with comparable technologies of other producers. What matters are the actual steps of the process in which students learn how to design and manage an 'intelligent' heating system.

Session 1: Zonal heating system technology

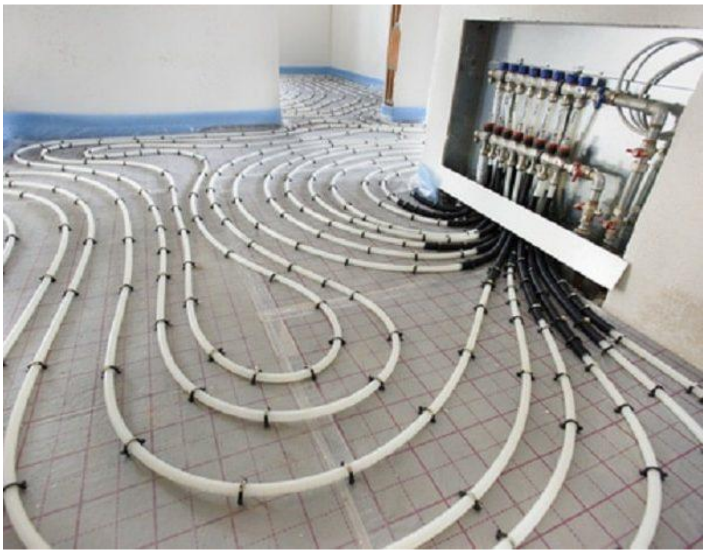
In this first workshop the students were introduced to the technology developed and produced by the firm and its various applications. In particular, they learned the basics of different zonal heating systems.

a) divided from the perspective of the steering point
   - located in the given room
   - controlled via the Internet

b) divided from the perspective of the installation method
   - wireless (using for communication a radio module 868Mhz)
   - wired (using appropriate wiring, 2 or 4-wires)

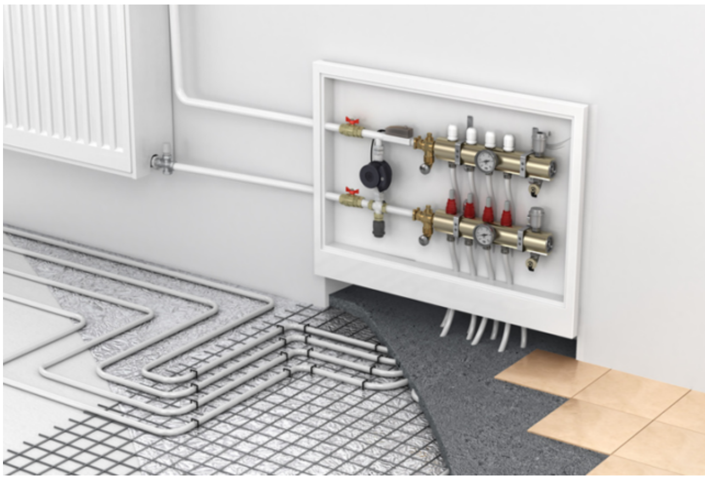
And different types of central heating systems.

a) floor heating



b) radiator heating

c) mixed heating



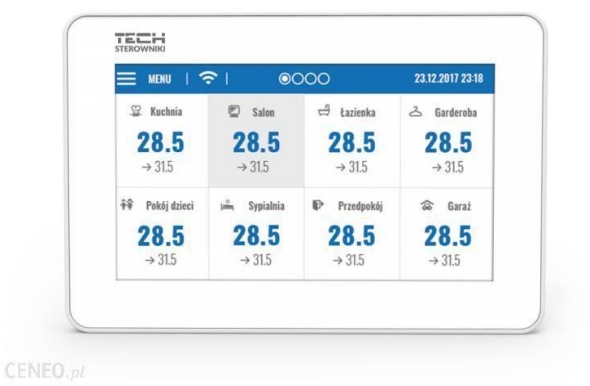
Particular attention was given to getting to know zone heating systems controlled via the Internet (getting to know the devices that make up the control system).

a) examples of indoor devices

SENSOR C8R - temperature sensor
C8R Manual

R8B REGULATOR - temperature controller
R8B Manual

b) M9 control device, cooperating with the L9r control strip



M9 Manual

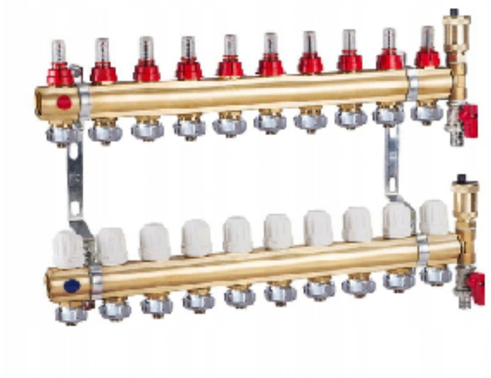
- allows you to change the temperature in each zone
- has a Wi-Fi module that allows you to connect the entire system to the Internet
- it must be wired with the L9 strip using a 4-core cable, additionally requires a 230V power supply

c) L9R control strip

L9R Manual

- ❖ wirelessly connects to the C8R sensor or the R8B regulator
- ❖ connects to the M9 via a 4-core cable
- ❖ enables wireless control of heaters

d) stt230 / 2t actuator



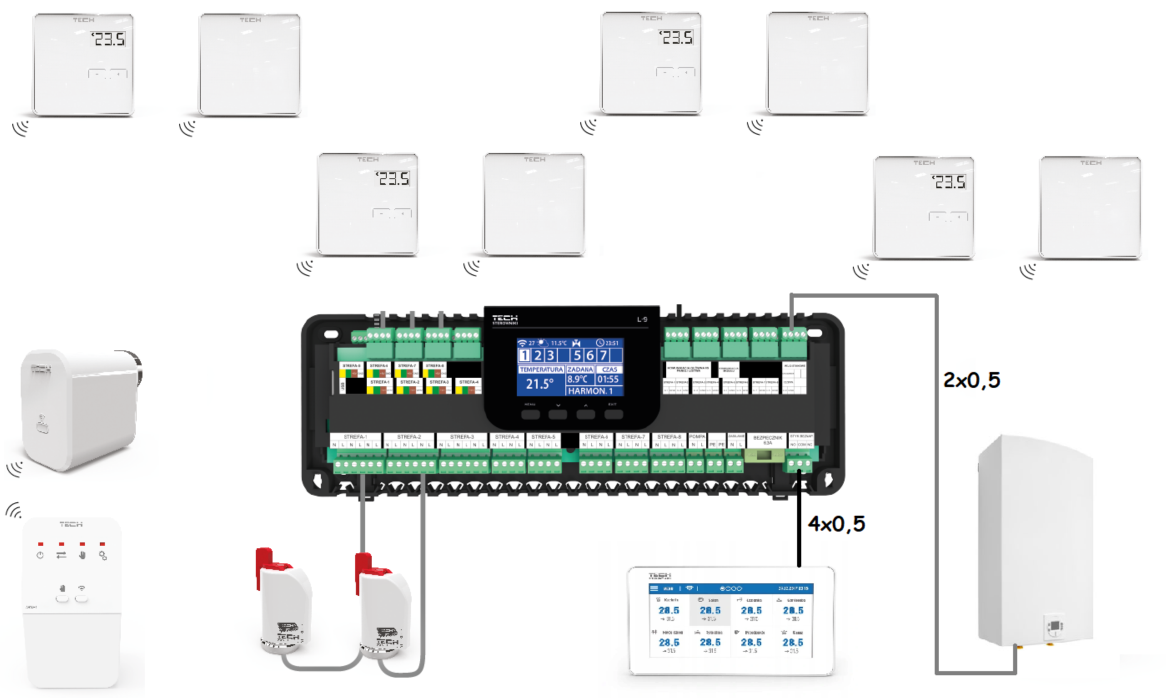
- ❖ Executive device (opens / closes the circuit to be heated up)

e) actuator stt869

STT869 Manual

❖ a wireless actuator that controls the heater

Connection diagram of the completed set



Management of an example heating system available at
https://emodul.pl/web/8623dddc28f834922d97b76f2096873c/home

Session 2: Solutions for improved wireless heating system management

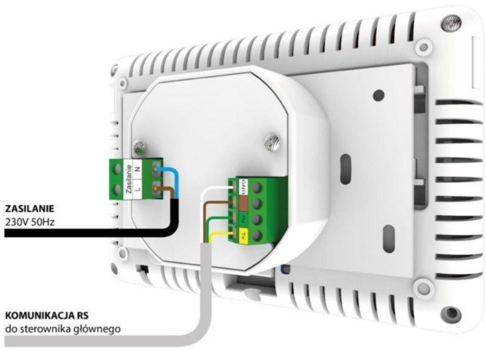
In the second workshop the students were given a challenge to design solutions for improved wireless heating system management. It was assumed that there are 8 independent rooms fitted with radiators in an old building with no zonal heating management system.

a) First, the equipment was completed:
  - 8x Regulator R8B
  - 1x M9
  - 1x L9r
  - 1x stt869

b) Then the students connected all the elements of the electronic installation.

- R8B regulators are powered by AAA batteries, they are connected to the L9r strip via a wireless network, and more precisely by means of a radio module operating at the frequency of 868Mhz.
- Each regulator is responsible for one zone. The difference between C8R, R8B is that on the controller we can additionally change the temperature from the position of the room in which we are located.
- The devices can be connected quickly: in the L9 device, go to Menu / zones / zone 1..8 / sensor / registration.
- When the device is in the registration mode, on the R8B regulator, on the back you will find the button to press. After a while a message will pop up, the device has been successfully registered. We do the same when registering each of the 8 regulators / sensors.
- The stt230 / 2t actuators can be connected to the L9r strip with which the R8B regulators are connected, which, depending on the set temperature in the room, will open / close. We connect the actuators with the strip to the designated place using the cable included in the kit.

- ❖ Wireless actuator stt869, has to be mounted on the radiator valve. We install AA batteries in it and the device will calibrate itself - it takes about 1,5 minutes. After calibration, in the L9r strip, we click Menu / Strefy / Zone 1..8 / Actuator / register. There is a button on the stt869 actuator which is used for connection. When you press it and the devices are connected, the message *actuator successfully registered* will appear on the L9r.
- ❖ We can connect the M9 to the prepared set. The M9 controller is connected to the L9r strip with a 4-core cable, and then connected to 230V.



- ❖ If the devices are connected correctly, they will control the heating system from the position of the house, it is useful when there is no Internet connection.
- ❖ The next step is to connect the M9 module to the Internet. The device connects via Wi-Fi. With the device turned on, we click Menu / Wifi network. We select the available Hotspot, enter the password and click connect.

Session 3: IoT platform for wireless management of heating systems

In the 3rd workshop the students were acquainted with the IoT platform - emodul.pl - developed by the host company. They created their accounts on the platform and downloaded control apps on their mobile phones.

The students registered on the platform, created and activated an account. Having an account on the platform, they were able to add a module with the code which can be found in the M9 driver settings.

he EMODUL application for smartphones with the Android system can be downloaded from the Play Store, and for mobile devices with the iOS system from the App Store.

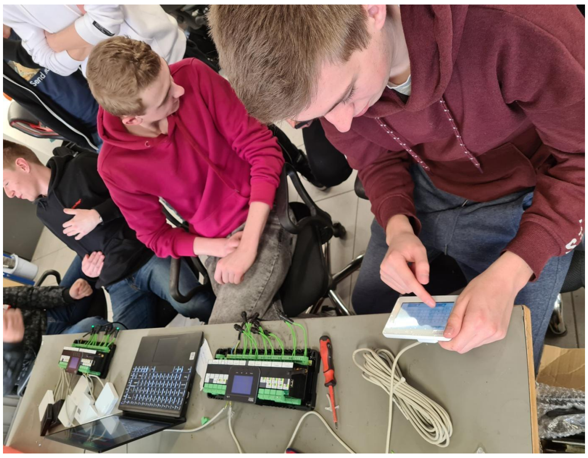
On the left side we have a screenshot of a Windows PC. On the right, a screenshot from an Android smartphone. We can change the settings from both devices, they are updated every minute.

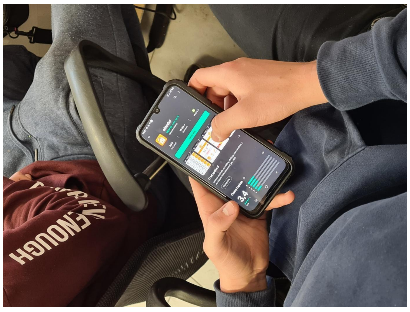
The students practised changing the name of the zone, the zone icon, and most importantly - the set temperature.

Session 4: Choosing the right equipment

The workshop host company, a manufacturer of wireless controllers, has a heating system configurator on its website: www.techsterowniki.pl/konfigurator-systemow/pl/typ

The task for the students during this final workshop was to design a wireless management system for heating appliances in an old building of their school. They had to select the appropriate number of sensors, regulators, control devices and actuators drawing on all the knowledge gained in the previous sessions.





Learning outcomes

Upon successful completion of the workshop, the students were able to:

- ❖ Explain the concept of IoT and its potential for energy saving
- ❖ Apply the knowledge and skills acquired during the workshop to design a complete network of devices to wirelessly manage a zonal heating system
- ❖ Implement the design in an existing building
- ❖ Control temperature in its different zones via an IoT app installed on their smartphones

2. Remote control of home monitoring

This scenario comprises a series of workshops for high school students on designing and managing a home monitoring system. The programme was developed and implemented by the two Polish partner organisations in the IoT project, EST and CKZU, as an extracurricular learning programme bridging a number of STEM subjects. The students were introduced to the relevant technologies and challenged with a task to design an 'intelligent' monitoring installation for a home building.

Relation to high school curriculum

Maths: reason quantitatively and use units to solve problems; perform arithmetic operations; reason abstractly and quantitatively; summarise, represent, and interpret data on a measurement variable; make inferences and justify conclusions from sample experiments and observational studies

Physics: design and perform experiments; value inquiry as the fundamental scientific process; identify variables and describe relationships between them; plan procedures to collect data on variables and control them; understand how more advanced electrical and electronic systems can be used in circuits; design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering

Information Technology: develop and apply their analytic, problem-solving, design, and computational thinking skills; use technology purposefully to create, organise, store, manipulate and retrieve digital content; understand what algorithms are, how they are implemented as programs on digital devices; design functional products using digital tools; apply computing and use electronics to embed intelligence in products that respond to inputs and control outputs

Grade Level: 9th - 12th

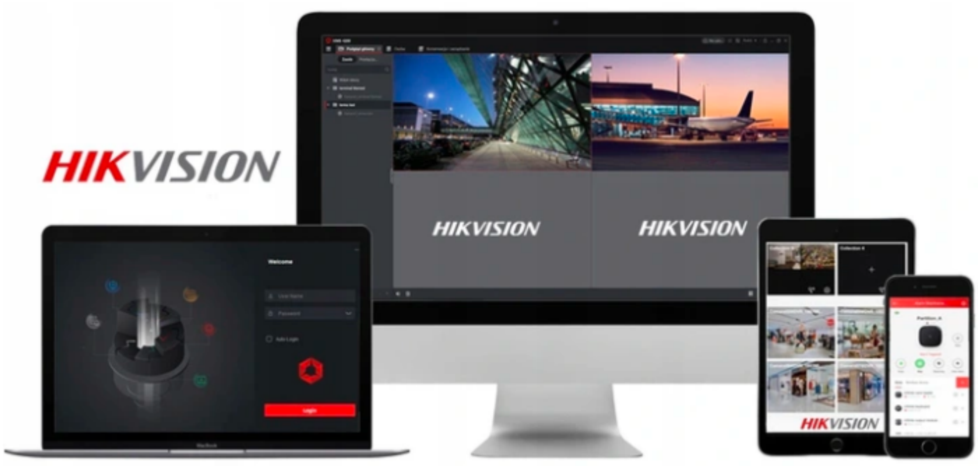
Estimated time: developed as a 4-session workshop (can be shortened or extended)

Materials & Technology

- Computer lab with at least 1 PC for a pair of students
- 4-channel IP recorder with PoE switch
- 4x 4Mpx tube camera (2560x1440 True 2.5k) - IPCAM-B4
- Hard disc for CCTV (recording 24/7) - Toshiba S300 1TB
- UTP twisted-pair cable
- Set of connectors and plugs
- IoT platform for wireless management of a monitoring system
- Smartphones for installation of relevant IoT apps

The workshops were facilitated by a close cooperation with a local company Tech Sterowniki, a major producer of controllers for intelligent heating systems. They helped us organise the practical activities for our students, offering a workshop lab, materials and a support trainer. In what follows we present the learning scenario divided into four workshops as it was actually implemented by us. We used concrete materials and tools provided by the host company. However, the same or similar activities can be conducted with comparable technologies of other producers. What matters are the actual steps of the process in which students learn how to design and manage an 'intelligent' home monitoring system.

Session 1: Home monitoring technology



In this first workshop the students were introduced to the respective technology.

Monitoring systems can be controlled, configured and operated using the intuitive **DMSS mobile application** for smartphones and tablets and the **SMARTPSS program for PCs**. Thanks to this, the user has constant control and supervision over the monitored space from any place on earth with access to the network. The application and the program allow for:

- live image preview
- remote playback of recordings
- creating scenarios and rules for traffic detection
- control of rotary cameras
- receiving notifications about events within the system

The application uses a P2P cloud, thanks to which the system does not need to have ports redirected on the router.

Particular attention was given to getting to know functions of the following two devices that make up the monitoring system.

a) 4-channel IP recorder with PoE switch

The students were acquainted with its following parameters:

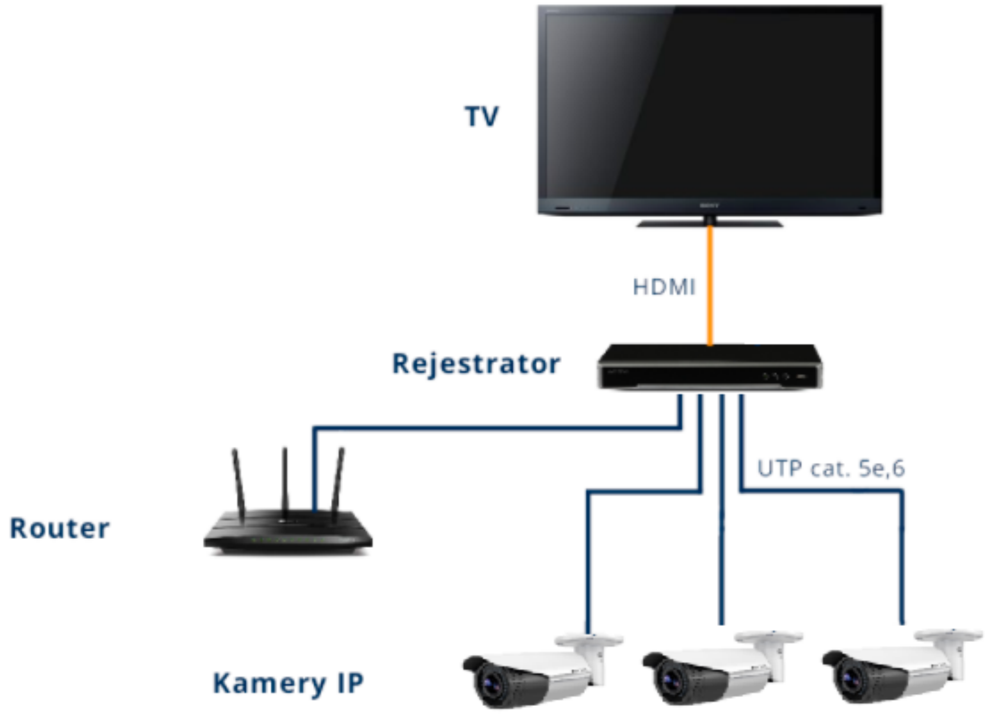
- Recording resolution
- Image decoding
- Video compression
- Network protocols
- Remote service using the Hik-Connect app

b) 4Mpx tube camera (2560x1440 True 2.5k) - IPCAM-B4

The students were acquainted with its following parameters:

- Image resolution
- Lens width
- Recording angle
- Image compression
- Dynamic range
- Infrared range
- P2P cloud support

The students also learned how to connect a completed set through this diagram:



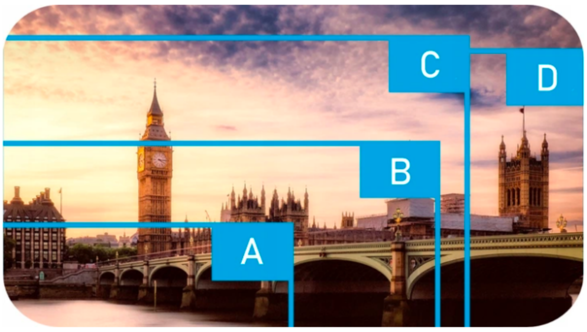
Session 2: The hardware capabilities

The students proceeded to learn how an example monitoring system works following the above diagram. The presentation focused on three aspects of its operations.

a) Resolution 2560x1440p

The IPCAM-B4 camera has a 4Mpx resolution that allows for much more accurate registration of details than standard FullHD models:

- A: HD 1280x720p
- B: FHD 1920x1080p
- C: 3Mpx 2048x1536p
- D: 4Mpx 2560x1440p



b) Motion detection

The presented model has a built-in motion detection algorithm - when moving objects are detected on the scene, the camera can send an alarm notification to the program and application.

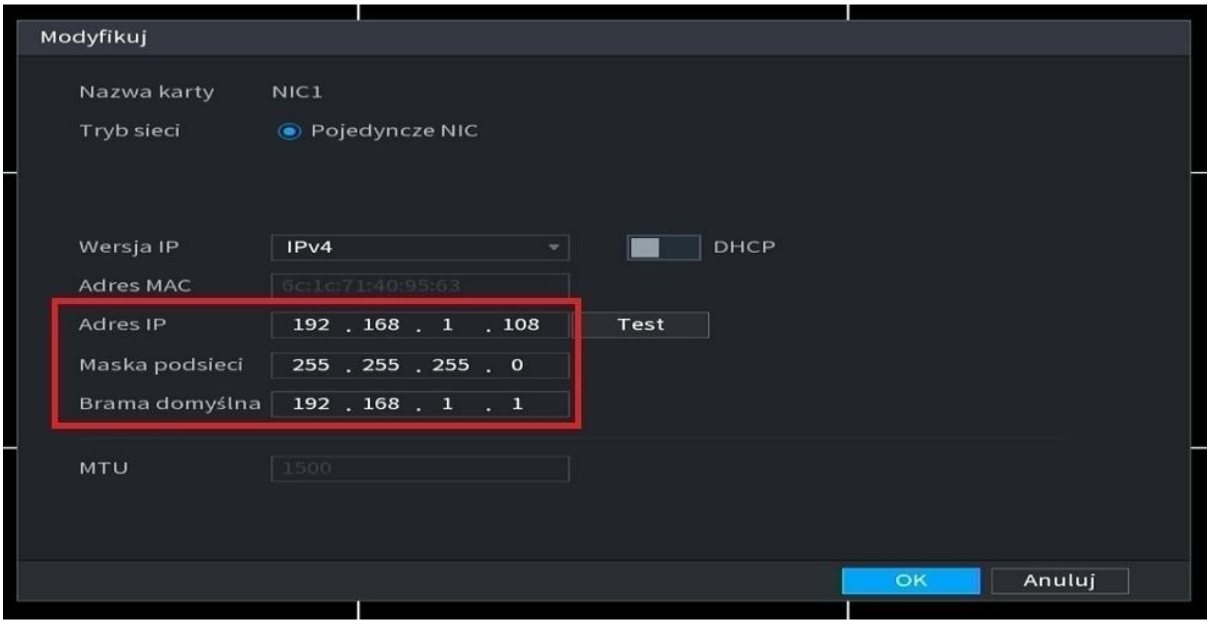
What's more, while recording in motion detection mode, the camera saves a lot of space on the hard drive, which has a positive effect on its lifespan.

c) Automatic night mode

The IPCAM-B4 camera is equipped with an automatic night mode - this means that when the ambient light decreases, the camera switches to black and white mode, supported by an IR illuminator with a range of 30 m. This feature allows you to record images 24/7 in any lighting conditions.

Session 3: Recorder initialisation

In the third workshop the students were given a task to configure and initialise the recorder. The procedure followed the particular settings of the chosen 4-channel IP recorder with PoE switch but similar steps can be followed with the use of a different device. We thus provide an example which can be adapted to the chosen technology. The illustrating screenshot shows the recorder's interface used by the students for the device configuration.



a) Password setting

The students created their own password according to the rules shown on the screen

b) Setting an unlock pattern

Each group had to create their own unlock pattern to be able to ensure only authorised use of the recorder.

c) Password reminder tools

We recommended the use of an email address for a possible device password reset. Additionally, it is possible to set up security questions.

d) Network settings

The students learned how to change the device's network settings by editing the pre-installed options in the menu and choosing either automatic or manual network settings.

e) P2P (connection to the cloud)

After enabling this function, it was possible to connect to the recorder remotely, with an application in the phone or a computer program.

f) Recording schedule

Finally, the students had to configure the recording process: either as recording all the time (General) or recording after a motion detection (Motion)

Session 4: Assembling the entire installation

Then the students had a task to assemble the whole monitoring system which required them to:

- mount a hard disk in the recorder
- pinch the appropriate number of cables with RJ45 plugs (5 wires)
- connect the entire installation into a whole (recorder - router, recorder - cameras, recorder - monitor)
- download the mobile application for Android "DMSS" and configure it
- download the program for Windows "SMARTPSS" and configure it
- remote control from mobile devices (live image, preview of the image saved on the recorder's hard drive)

In what follows we summarise the most demanding steps.

a) Connection of the recorder with the DMSS application

Before starting the configuration, the students connected their phone to the wifi network to which the recorder is wired and downloaded and installed the DMSS application from this link:

https://dvspolska.pl/img/cms/PLIKI_INSTRUKCJE/DMSS_aplikacja.zip

To add the device to P2P, they had to enable the P2P option in the recorder settings, and activate the status "online". They also had to give the recorder their name, enter its password (given during the first activation of the recorder) and confirm the settings.

b) Connection of the recorder with the SmartPSS program

Before starting the configuration, the students connected the computer to the network to which the recorder is wired connected and downloaded and installed the SmartPSS application from this link:

https://dvspolska.pl/img/cms/PLIKI_INSTRUKCJE/SmartPSS_aplikacja.zip

To activate the recorder, they had to scan the available devices on the list, choose the relevant device, enter the login and password set during the recorder configuration, and enable the online live view.

Having followed all the above steps, the students could test the remote control from their mobile devices to monitor live images from the installed cameras.

Learning outcomes

Upon successful completion of the workshop, the students were able to:

- Explain the concept of IoT and its potential for remote control of home monitoring
- Apply the knowledge and skills acquired during the workshop to design a complete home monitoring system
- Remote control of motions in a given space with the use of a mobile application for smartphones and a program for PCs

3. Smart home - intelligent home

This scenario comprises a series of workshops for high school students on designing and managing various ‘smart’ home applications. The programme was developed and implemented by the two Polish partner organisations in the IoT project, EST and CKZU, as an extracurricular learning programme bridging a number of STEM subjects. The students were introduced to the relevant technologies and challenged with a task to design an ‘intelligent’ home system.

Relation to high school curriculum

Maths: reason quantitatively and use units to solve problems; perform arithmetic operations; reason abstractly and quantitatively; summarise, represent, and interpret data on a measurement variable; make inferences and justify conclusions from sample experiments and observational studies

Physics: design and perform experiments; value inquiry as the fundamental scientific process; identify variables and describe relationships between them; plan procedures to collect data on variables and control them; understand how more advanced electrical and electronic systems can be used in circuits with heat; design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering

Information Technology: develop and apply their analytic, problem-solving, design, and computational thinking skills; use technology purposefully to create, organise, store, manipulate and retrieve digital content; understand what algorithms are, how they are implemented as programs on digital devices; design functional products using digital tools; apply computing and use electronics to embed intelligence in products that respond to inputs and control outputs

Grade Level: 9th - 12th

Estimated time: developed as a 6-session workshop (can be shortened or extended)

Materials & Technology

- Computer lab with at least 1 PC for a pair of students
- 1 smartphone with android/iOS
- 1 central unit Sinum EH-01
- Wireless control devices (roller blinds, lighting, temperature regulators)
- 1 wireless motion detector
- Wireless actuators
- 1 wireless "button"
- Platform https://sinum.tech/login

The workshops were facilitated by a close cooperation with a local company Tech Sterowniki, a major producer of controllers for intelligent heating systems. They helped us organise the practical activities for our students, offering a workshop lab, materials and a support trainer. In what follows we present the learning scenario divided into six workshops as it was actually implemented by us. We used concrete materials and tools provided by the host company which can be learned in more detail through the links given throughout the text. However, the same or similar activities can be conducted with comparable technologies of other producers. What matters are the actual steps of the process in which students learn how to design and manage a 'smart' home.

Session 1: Introduction to the concept of a smart home

Smart home technology integrates all systems necessary for intelligent home management. These systems allow you to manage lighting, power supply, heating, as well as other devices in the garage or garden. Controlling of a smart home system can be done via the Internet using Android/iOS and a computer.

During the first class, students were introduced to the smart home technology developed and manufactured by the company and its various applications. In particular, they learned about the capabilities of the system and its advantages. They learnt how appropriate actions of the smart home user can be used and conditioned, adjusting output devices to motion sensors.

a) The most important control areas of SMART HOME:

- Heating - viewing, increasing or decreasing temperature
- Lighting - checking, switching on and off the light
- External blinds - lowering and raising the blinds
- Sensors (smoke, humidity, air purity) - ensure safety throughout the day
- Alarm systems and home monitoring

b) The advantages of a smart home:

- Increased functionality of the premises
- Increased security level
- Increased comfort of living
- Full comfort of use
- Reduction of operating costs
- Reduced emission of pollutants into the environment

Session 2 & 3: Start-up of the EH-01 control panel. Getting to know the products cooperating with the panel and their capabilities

The heart of the entire smart home system is the EH-01 Control Panel:

This device is powered by a 24v adapter and can be connected to a router or switch via an Ethernet cable. Thanks to the Ethernet port or the Wifi connection you can connect the control panel to the Internet and control the "whole house" via smartphone, tablet or computer from anywhere in the world. In the absence of the Internet, the smart home is still working and alert on the local Internet network.

EH-01 has 2 additional MODBUS inputs to control external devices supporting this protocol.

Using 868Mhz wireless communication with the control panel we can connect all input/output devices.

Input devices can be named as:

- Thermoregulators and lighting switches - by means of a thermoregulator you can control the temperature of each room, the change of state is sent to the control panel and it sends a signal to the executive devices and starts the heating device. The second part of the set allows you to switch on the lighting in the room. You can control 2 circuits (respectively 1 and 3 buttons) and the middle button is the so-called "mobile" and you can assign it an additional task (One of the tasks may be switching on both side circuits at the same time, or opening all the roller blinds in the house).

❖ Roller shutter switch - with these devices you can control lighting (2 circuits) and external or internal roller shutters; the roller shutters must have an electric motor.

❖ Button - a magic button which is coded in the control panel, to which you can assign special tasks - commands, and everything depends on how long you press the button or what sequence of clicks is performed. We can assign a few actions to it : each action must be different from the others (e.g. action 1 - single click - activates all the lights in the house, action 2 - two quick clicks - opens all the roller blinds, action 3 - one click for 3 sec - closes all the roller blinds in the house).

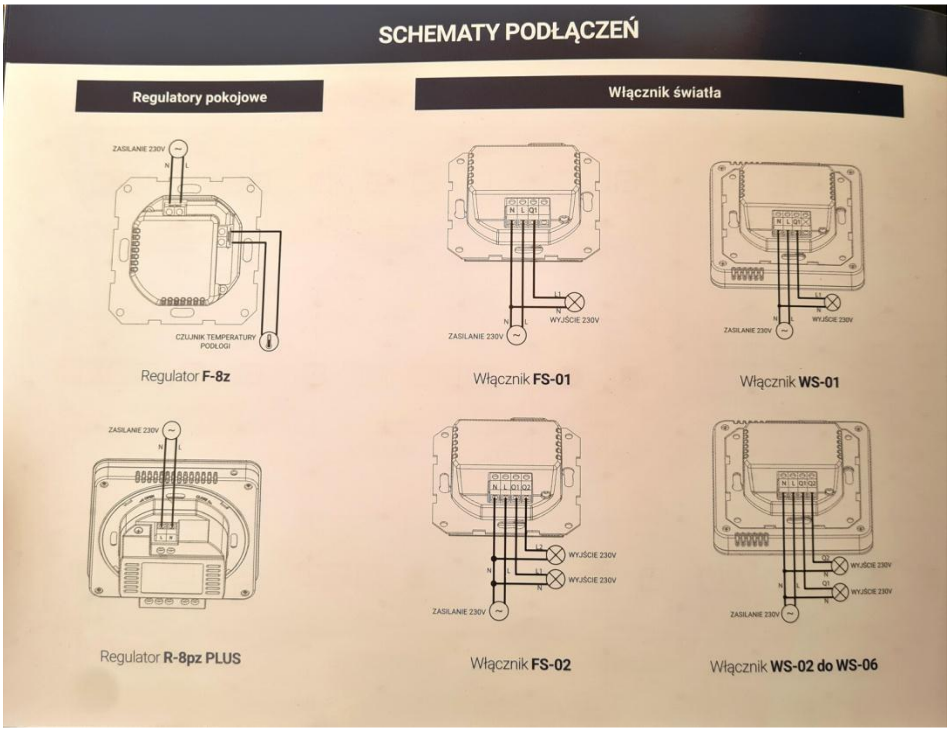
❖ Motion detector - a device powered by 1.5V batteries - thanks to this device you can control and assign various actions. The device is paired with the control panel and the functions are assigned to it, e.g. if after 6 p.m. it detects movement, the control panel will switch on the lighting in a given zone, you have to remember to switch it off. You can also assign another action to the device, i.e. to switch off the lighting if no one passes by during the next 5 minutes.

❖ Output devices are special executive modules that are controlled by sending commands from input devices.

Session 4: Electrical and electronic installation - connection, diagrams

Every device that is to perform a function and is connected to 230 volts must be signed according to the diagrams. For this, relevant knowledge of electronics and electricity is needed.

Smart home controllers, due to the wireless communication between each other can be installed in existing homes, as well as newly constructed buildings. Each student received an assembly kit. Below is an example of a wiring diagram, which the students had to follow strictly for health and safety reason:



Session 5: Creation, configuration of an account on the sinum.tech platform

Correctly performed connection of all components already allows you to control your home.

1. To make your home smart you create an account on http://sinum.tech/login
2. EH-01 must be connected to your home network via Ethernet cable.
3. After setting up the account you have to add the control panel to your account, the EH-01 control panel will be found automatically in the local network.
4. On your account at http://sinum.tech/login you will find the menu.

+ KOKPIT - tab where you can add devices to rooms, assign their functions and tasks. You can add switches, regulators, roller blinds, sensors or magic buttons.

+ HOME - a tab where you divide your home into zones, in which devices will be assigned. Zone is a room in which we can assign a few devices. For example: light switch, roller blinds, temperature regulator.

+ SCENES - a tab where you assign scenes, e.g. you can assign from all zones closing of roller blinds. We call the scene "Cinema" and assign to it the closing of all the roller blinds in the house and dimming of the lights.

+ AUTOMATION - you can assign the automation of a device, e.g. "turn on the outside light "if" it is 19:00"

+ STATISTICS, this tab presents graphs, by means of which we know what the temperatures are in the rooms, at what times in which zones the light was switched on, etc.

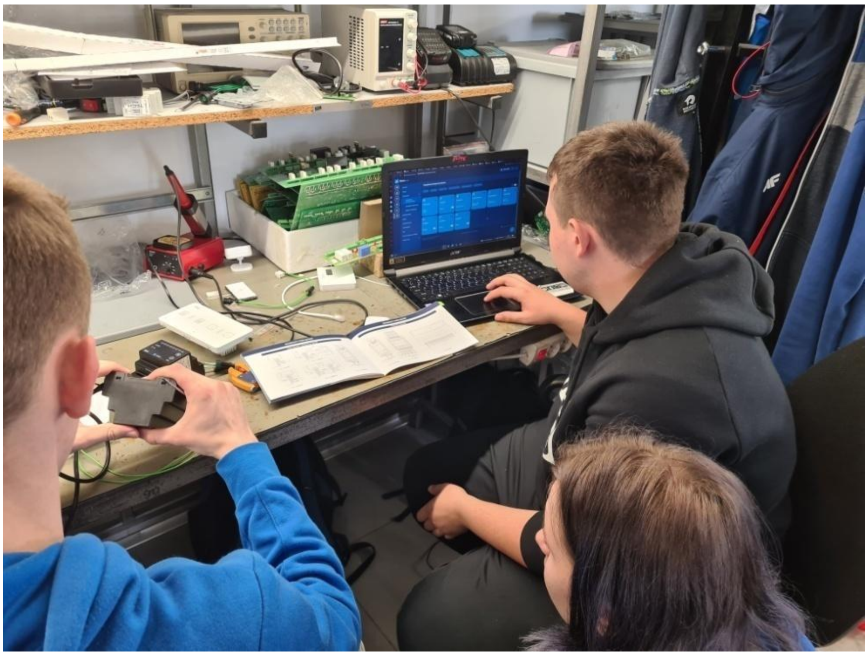
+ SETTINGS, a place where you can change the password to your account, update the online control panel, check the list of assigned devices, save data on the memory card in the EH-01 control panel

The configuration of a smart home is very intuitive and 99% depends on the user, and is programmed only via a computer and the Sinum.tech platform. The application can be downloaded from Google Play and you log in with the same data as your account on the platform. If you want to programme or add devices from your phone, the application will trigger the browser on your phone.

Session 6: Design of intelligent control in a newly erected single-family building

The company where the workshops were run and the manufacturer of the devices provided a catalogue in a paper form which contained all the available controller configurations.

The students' task was to design a smart home system in a newly constructed single-family building. They had to choose the right number of control devices for each room, sensors and actuators.



Learning outcomes

Upon successful completion of the workshop, the students were able to:

- Explain the concept of IoT and its potential for energy saving
- Apply the knowledge and skills acquired during the workshop to design a smart home
- Assemble and configure a set of relevant devices
- Control temperature in different zones via an IoT app installed on their smartphones
- Control the operation of external blinds
- Control the lighting (they can switch the lighting on and off in the appropriate zones)

4. The IoT: Comfort level in a classroom – Measurement of temperature, humidity, light level and CO_2

“Curricular autonomy” (DAC) is an area which favours interdisciplinary work. Its delivery aims the Essential Learning Targets (AE) of the different curriculum subjects by fostering project work. Thus, the learning scenarios we here present address project work in Maths, Physics and Chemistry, and ICT.

The first workshop in Tavira, Portugal was designed by teachers from Dr. Jorge Augusto Correia School and implemented in the formal curriculum during school time; it was also run by the Science Club as an extracurricular activity. The topic of the workshop relies on numerous studies of the physical conditions of classrooms and its impact on students' productivity. This topic is quite relevant as we must bear in mind that it is directly linked to students' daily lives due to the climate characteristics of the Algarve and the lack of thermal insulation in classrooms.

The planning of this learning workshop is student-centred right from the start (design moment), going on to the development stage and, finally, the assessment moment.

Curriculum Framework (Essential Learning Targets)

The student must be able to:

Maths

- Use statistical information to solve problems and make informed, reasoned decisions;
- Collect, organise, represent data and understand the represented information;
- Represent graphically two-dimensional distributions;
- Solve problems involving the organisation and processing of data in varied, familiar contexts;
- Develop the ability to analyse his work and assess his learning;
- Develop persistence, autonomy and ease in dealing with situations involving mathematics.

Physics and Chemistry

- Consolidate, deepen and broaden knowledge by understanding concepts, laws and theories that describe, explain, and predict phenomena, as well as underlie its use in different situations and contexts;
- Analyse and interpret in relevant contexts physical and chemical phenomena with impact on technology, society and the environment;
- Use different audiovisual media and ICT in the observation and description of phenomena in specific contexts, do bibliographical research, present, question, justify and assess;
- Reveal responsibility, accuracy, autonomy, scientifically based critical thinking, strong sense of collaboration and curiosity.

Computer programming (PSI)

- Develop knowledge and skills for algorithms; programming languages; research work on the use of the components; Arduino Installation and Assembly; and creating Applications for Mobile Devices (APP);
- Increase collaborative production skills, focusing mainly on co-creativity and co-responsibility, which enhance open-mindedness for change;
- Develop skills for working with computer applications for specific learning and other training areas;
- Create habits and attitudes for lifelong learning as an essential condition for adjusting to new ways of communicating, which are rapidly expanding.

Grade Level: 10th - 12th

Estimated time: developed as a 4-session workshop
(If these sessions are to be held on the formal curriculum, then some sessions may be simultaneous)

Materials & Technology (per group)

- 1 Computer
- 1 Arduino Uno R3 CH340 USB Cable
- 1 Temperature / Humidity sensor
- 1 CO2 sensor
- 1 Ambient light sensor [Optical Photosensitive]
- 4 Mini Self-Adhesive Breadboard
- 1Jumper Wires M/M Pack of 65 mixed colours
- Lab. Material (session 1)

Session 1: Research and introduction to basic concepts (Physics and Chemistry)

The session began by clarifying what one needs to know to be able to answer the problem question and make the connection with the essential learning targets of the subject of Physics and Chemistry. The problem question - Are the CO_2 levels, temperature, light level or illuminance and humidity within the limits considered comfort enhancers in a classroom? The exploration of the topics was done by a laboratory experimental activity/ or a magazine article to promote the discussion on each of the contents to be worked on. Through guided dialogue, the teacher listed the predictions presented and the alternative conceptions. This activity enhanced the essential learning targets and thus allowed students to build new knowledge.

Carbon dioxide, CO_2

The activity consisted in the production of CO_2 through the chemical reaction of acetic acid with baking soda. CO_2 was collected in an open container with a rectangular base. The students then slowly approached a lit match from top to bottom, and it went out at the bottom. After session 2 this activity can be revisited using the CO_2 sensor.

In the Earth's atmosphere, CO_2 is present in relatively small quantities, but its concentration in the atmosphere is increasing. The monitoring of greenhouse gases (CO, CO_2, and CH_4) has been done in Portugal since 1979, with samples collected on Terceira Island, Azores. These levels can be found at
https://www.ipma.pt/pt/oclima/gases.estufa/index.jsp.

The discussion which followed focused on what is done, and what could be done, either individually or as a whole by the country, to reduce greenhouse gas emissions.

And in a classroom, what is the main factor responsible for the increase in CO_2? How can we measure it? What are the units in which it is expressed?

The quantitative composition of solutions which contain a small proportion of solute can be expressed in ppm. This introduction is needed for the essential learning targets that must be met, as well as the units used in the programming of the sensors and its analysis in the following sessions.

Temperature

The introduction of this second parameter started with a discussion of the average temperatures in the Eastern Algarve, which can be found at
https://www.ipma.pt/pt/oclima/monitorizacao/index.jsp?selTipo=g.

The discussion allowed the identification of alternative conceptions of heat and temperature. To work on these concepts, an experimental activity was performed using simple laboratory equipment. The Laws of Thermodynamics were the basis for interpreting the processes and mechanisms of energy transfer between thermodynamic systems.

And in a classroom, what is the main factor responsible for the temperature increase? How can we make its measurement? What are the units in which it is expressed?

Humidity

This parameter is not part of the essential learning targets, so you can promote discussion of real situations and argue based on scientific knowledge. This discussion can be held using the article that can be found at: “Damp rooms can affect school performance”, Educare - The Education Portal.

Light level or Illuminance

Through these activities, the following essential learning targets are met: Understand the emission of light when there is a transition from a higher energy electronic level to a lower one; research the processes involved in different sources of natural and artificial light, identifying the interactions that give rise to light and, finally, communicating the results.

Session 2: Project design with Arduino and Assembly (Programming Computer Systems - 10th grade)

To develop this second session of the workshop, a platform that is very useful when you want to develop IoT projects, Arduino, was used. Arduino is an open source platform that includes hardware and software components with a set of libraries that help to program microcontrollers. Arduino - Home.

To take CO_2, temperature, humidity and Illuminance readings in the classrooms, sensors connected to Arduino boards were used to interface with the computer. The circuit can be designed, programmed and simulated without Arduino boards, using the free online platform, *Tinkercad*, which can be found at https://www.tinkercad.com/.

This application proved to be an asset for non-face-to-face classroom situations.

The assembly drawings were handed out to the students. The time this task takes up and the expected learning targets are different whether one chooses to provide the assembly plan or ask students to research and draw the project.

Project design. Simulation situation.

- In a simulation situation *Tinkercad* was used, circuits we implemented, and the code and the components were tested.

Hardware connection. Connecting virtual reality to reality.

- Bearing in mind the designed project, the implementation was done in Arduino, making the connections of the components.

Installing the Arduino application on the computer - Software | Arduino

- Generate the code that will make the hardware work.
- Or export the code from *Tinkercad* to the circuit. The code base is already given; however, it is necessary to optimise it in the real circuit.

The sensors already have the data needed, but the students were asked to insert the comfort values researched before because this is an interdisciplinary project.

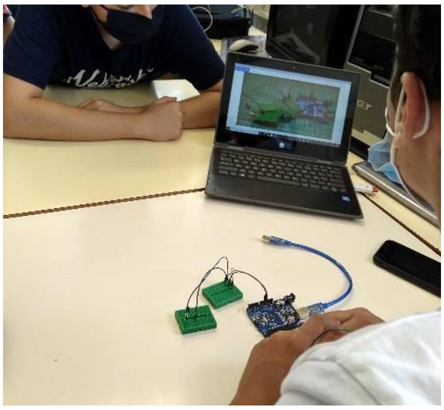


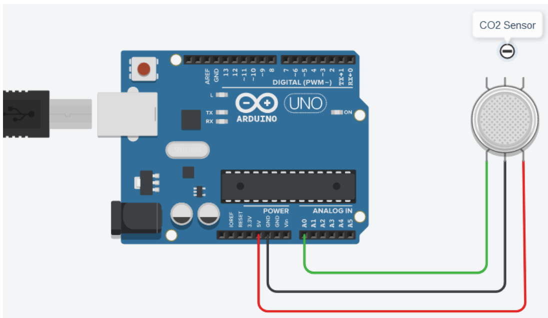
Figure 1 and 2 - Students assembling the circuit

CO_2 Sensor

SGP30_Gas_Sensor-master

Code:

```
#include "sgp30.h"

s16 error;
u16 tvoc_ppb, co2_eq_ppm;

void setup() {
        Serial.begin(9600);

        //Init module,Reset all baseline,The initialization takes up to around 15
        //seconds, during which all APIs measuring IAQ(Indoor air quality ) output
        //will not change.Default value is 400(ppm) for co2,0(ppb) for tvoc
        while (sgp_probe() != STATUS_OK) {
                Serial.println("SGP failed");
                while (1);
        }
}

void loop() {
        error = sgp_measure_iaq_blocking_read(&tvoc_ppb, &co2_eq_ppm);
        if (error == STATUS_OK) {
                Serial.print("tVOC: ");
                Serial.print(tvoc_ppb);
                Serial.println("ppb");

                Serial.print("CO2eq: ");
                Serial.print(co2_eq_ppm);
                Serial.println("ppm");
        } else
                Serial.println("Error Reading!\n");

   delay(1000);
}
```



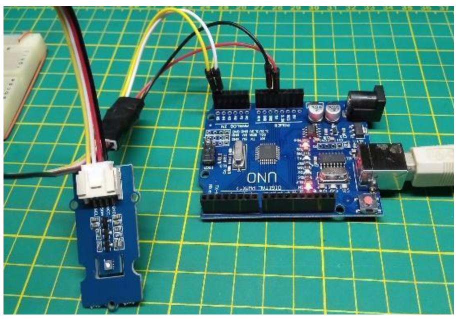


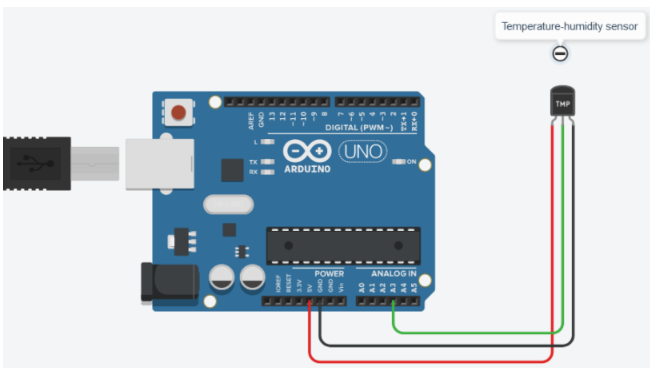
Figure 3 and 4 - Circuit diagram on Tinkercad and photo of the circuit assembly (SGP30)

Temperature and humidity sensor

DHT22 Temperature - humidity sensor

Code:

```
//Módulo DHT22 sensor temperature/humidity
#include <DHTesp.h>
#define sensor 5

//Sensor variable
DHTesp DHT1;
float temperature, humidity;

void setup() {
        Serial.begin(9600);
        DHT1.setup(sensor, DHTesp::DHT22);
}

void loop() {
        // put your main code here, to run repeatedly:
        //Reading values
        humidity = DHT1.getHumidity();
        temperature = DHT1.getTemperature();

        //Reading values
        humidity = DHT1.getHumidity();
        temperature = DHT1.getTemperature();
        Serial.print( "Humidity: " );
        Serial.println( humidity );
        Serial.print( "Temperature: ");
        Serial.println( temperature );
        delay( 2000 );
}
```



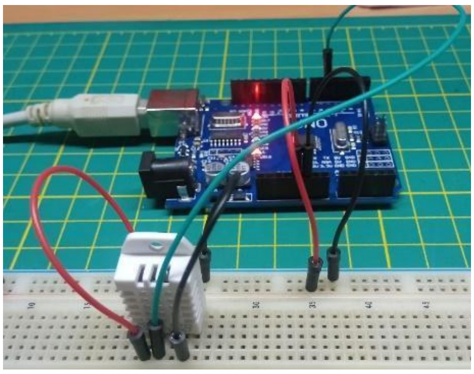


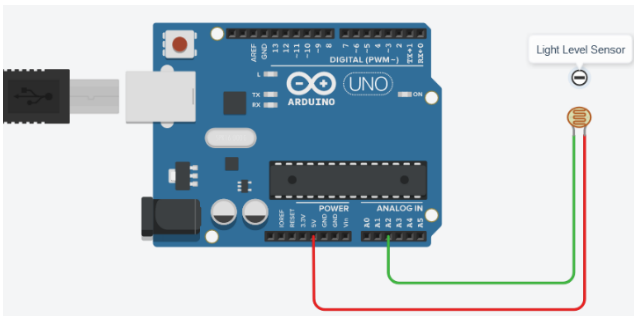
Figure 5 and 6- Circuit diagram on Tinkercad and photo of the circuit assembly (DHT22)

Light level or Illuminance

LDR - Light Controlled Resistor 1M 250mW

Code:

```
#define pin_LDR A0
double VOLTAGE = 5; //5 volts
double CURRENT;
double RESISTANCE = 10000; //Auxiliary Resistor 10k
double LDR; //LDR sensor readings
double LUX; //LUX sensor readings (light unit per m2)

void setup() {
        // put your setup code here, to run once:
        Serial.begin(9600);
        pinMode( pin_LDR, INPUT );
}

void loop() {
        // put your main code here, to run repeatedly:
        LDR = analogRead( pin_LDR );
        delay(2000);

        //Aply fórmula LUX = 255,84 * R pow(-10/9)
        //General fórmula (V = I * R) <=> (VOLTAGE = CURRENT * RESISTANCE)
        VOLTAGE = LDR * 5 / 1023;  //1023 maximum value of LDR when at 5 volts
                                   //(LDR = 0 => 0volts; LDR = 1023 => 5volts)
        CURRENT = VOLTAGE / 10000;        //Auxiliary Resistor 10k
        RESISTANCE = (5-VOLTAGE) / CURRENT;
                                   //RESISTANCE = VOLTAGE / CURRENT;

        //Serial.println( VOLTAGE );
        //Serial.println( CURRENT );
        //Serial.println( RESISTANCE );
        LUX = 255,84 * pow( RESISTANCE, -10/9 );

        Serial.print( LUX );
        Serial.print( "  " );
        Serial.println( LDR );
}
```



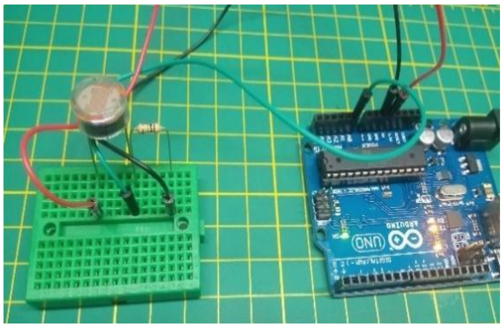
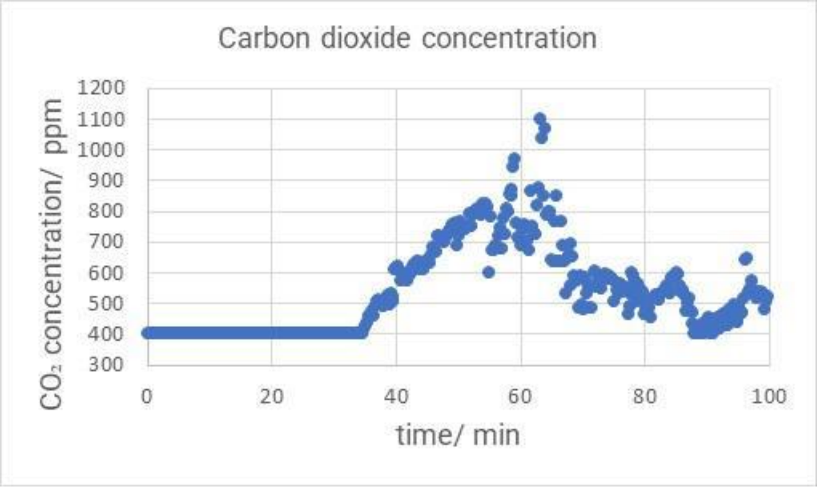


Figure 7 and 8- Circuit diagram on Tinkercad and photo of the circuit assembly (LDR)

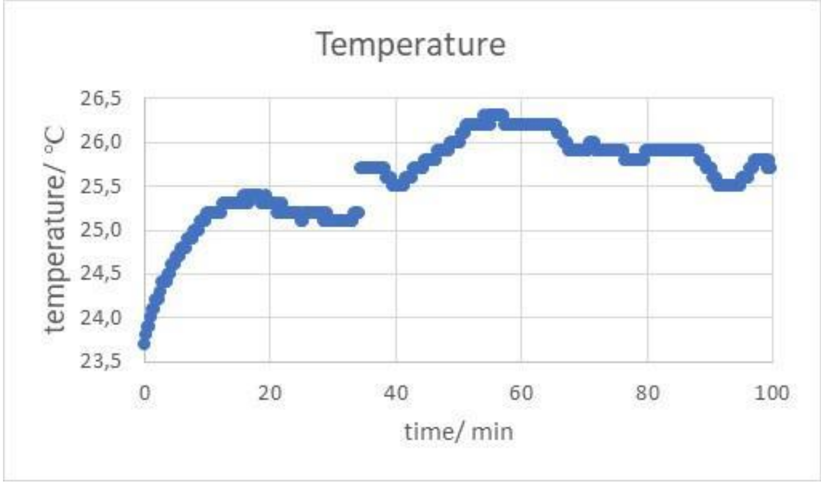
Session 3: Data processing and analysis of results (mathematics)

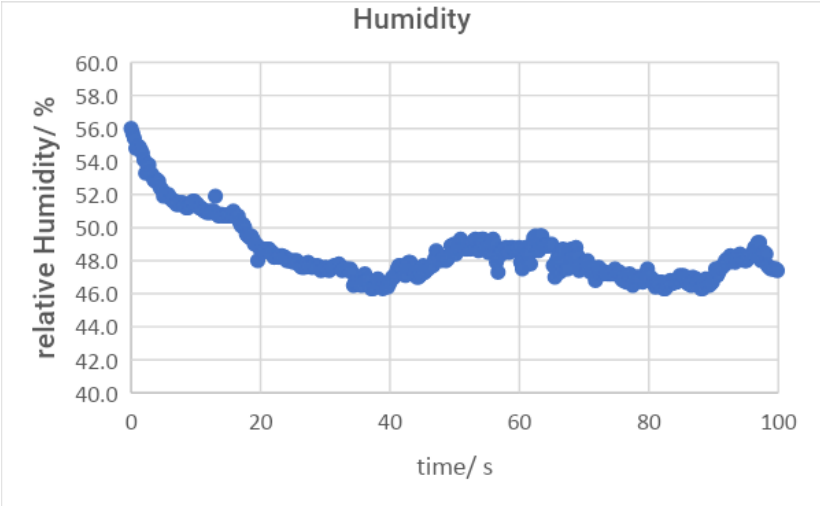
This session began by asking the students to estimate the area and volume of the classroom where the sensors will be applied. Then, the data were related to the discussion held in the first session. The data collected by the sensors (in session 2) were organised in table form in the Excel program. Scatter diagrams were used to graph the data and possible correlation was intuitively analysed.

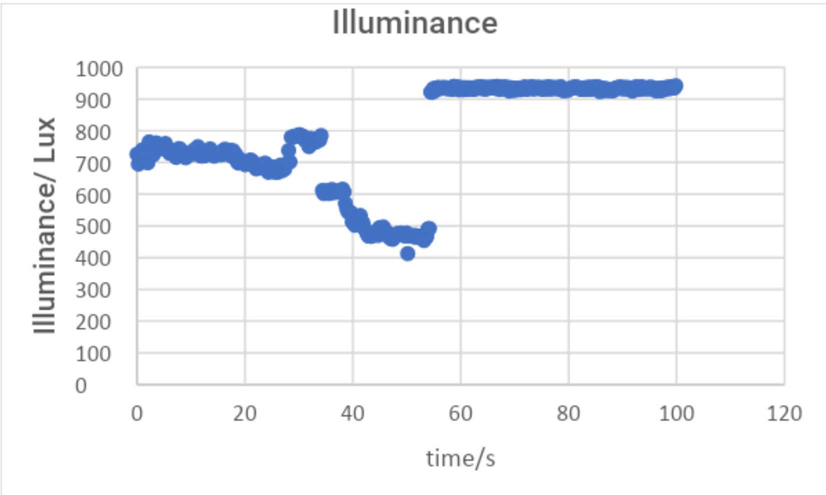
The following data was obtained on 21/6/2021, in a classroom with an area of 59,3 m^2, a volume of 169 m^3 and with 26 students present. The following graphs represent, respectively, the variation of the CO_2 concentration, temperature/humidity, and illuminance as a function of time.



Note: the value 400 ppm is the average concentration of CO_2 in the atmosphere.







Before closing the session, the students were asked to write a paragraph explaining the variations registered.

Note: In this classroom, when the levels of CO_2 or temperature are high, natural cross ventilation is used.

Session 4: the APP (Programming Computer Systems - 12th grade)

To carry out an IoT project, an informative APP was created to analyse the reference values. It was created in the *MIT APP Inventor* and can be used on mobile devices (Android).

MIT App Inventor, also known as App Inventor for Android, is an open source application originally created by Google, and currently maintained by the Massachusetts Institute of Technology. To carry out the APP, students must know basic programming and databases. To streamline the communication between App users and comment on the results, a chat associated with the APP was created. A **Google account** was also created for sharing resources and make dissemination. Most of the icons were created by students in **Inkscape**, applying the colour theory.

Create / customised logos / icons

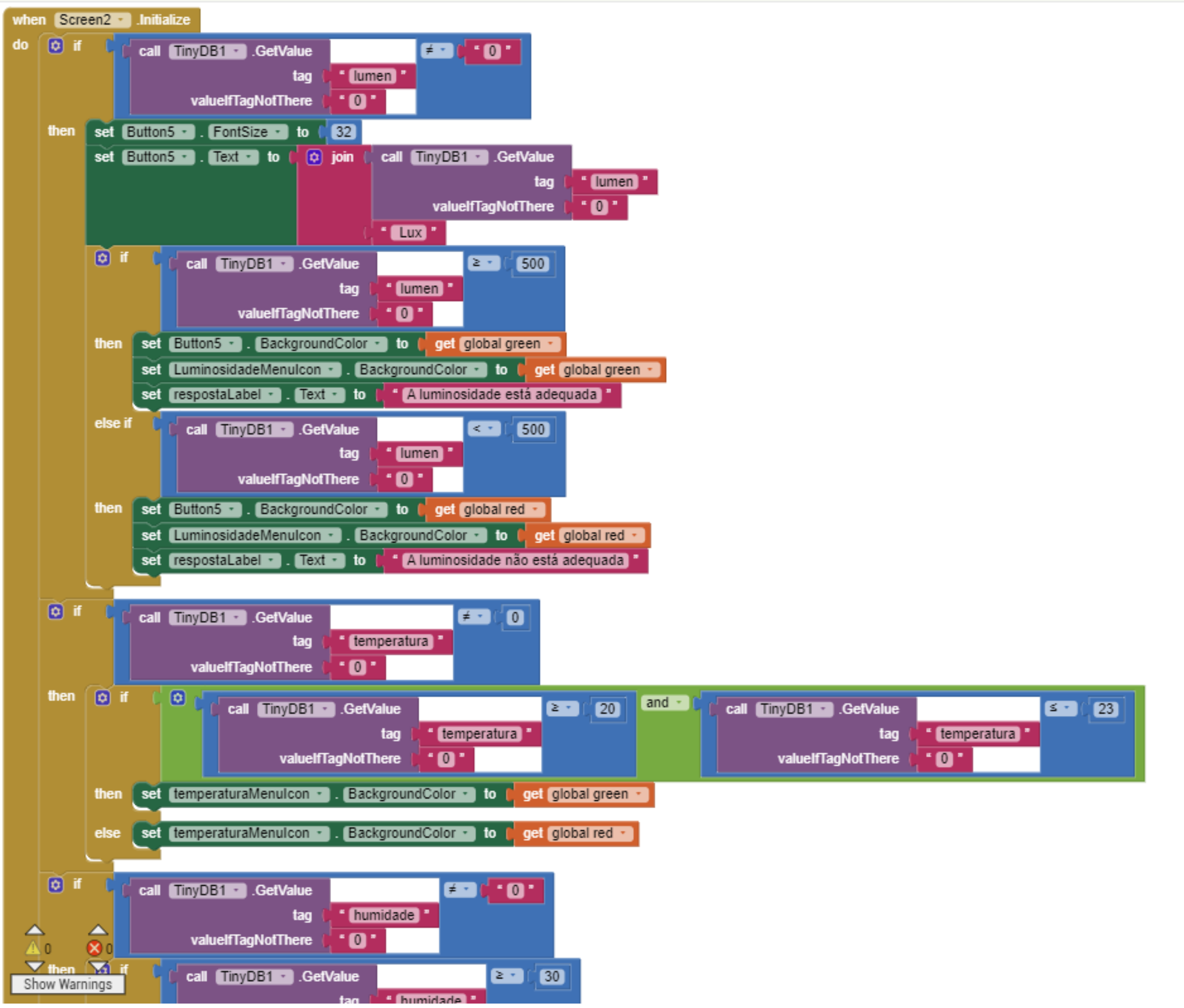
Figure 9 and 10 - Customised logos and icons created by the students

Conceiving and creating the interface design
Colour matching (colour theory) studying and its use in the design, specifications, "prototyping".

Creating an email account associated with the app; Firebase project configuration; Chat creation

User: appchatiot21@gmail.com
PW: appchatescola

Coding the App in MIT App Inventor (Implementation): translation of the defined functionalities into programming language.



Near the end of the session, validation tests of the application were performed.

Learning outcomes

This activity, contextualised and interdisciplinary, allowed students to:

- develop confidence in their mathematical skills and knowledge
- apply their knowledge in the context of real life situation
- solve the proposed challenges showing critical and creative thinking

5. Do face masks influence the concentration of gases we breathe?

The second workshop in Tavira was designed by teachers from Dr. Jorge Augusto Correia School and implemented both in the formal classroom curriculum and in a Science Club. Low cost, accessible programming technology was needed. Therefore, the *Arduino* technology was once again our best choice, as the variety of its sensors makes it effective for data collection.

The research problem question arose from the pandemic situation experienced, “Does the use of a mask influence the gas exchange of CO_2 and O_2?”

Curriculum Framework (Essential Learning Targets)

The student must be able to:

Maths

- Collect, organise, represent data and understand the information representation;
- Represent graphically two-dimensional distributions;
- Develop the ability to analyse his own work and assess his learning;
- Develop persistence, autonomy and ease in dealing with situations involving mathematics.

Chemistry

- Consolidate, deepen and broaden knowledge by understanding concepts, laws and theories that describe, explain and predict phenomena, as well as underlie its use in different situations and contexts;
- Analyse and interpret in relevant contexts physical and chemical phenomena with impact on technology, society and the environment;
- Use different audiovisual media and ICT in the observation and description of phenomena in specific contexts, do bibliographical research, present, question, justify and assess.
- Reveal responsibility, accuracy, autonomy, scientifically based critical thinking, strong sense of collaboration and curiosity.

Computer programming (PSI)

- Develop knowledge and skills for algorithms; programming languages; research work on the use of the components; Arduino Installation and Assembly;
- Increase collaborative production skills, focusing mainly on co-creativity and co-responsibility, which enhance open-mindedness for change;
- Develop skills for working with computer applications for specific learning and other training areas;
- Create habits and attitudes for lifelong learning as an essential condition for adjusting to new ways of communicating, which are rapidly expanding.

Grade Level: 11th
Estimated time: developed as a 2 - session workshop (1 joint session)

Grade Level: 12th
Estimated time: developed as a 2 - session workshop (1 joint session)

Materials & Technology (per group)

- 1 Computer
- 1 Arduino Uno R3 CH340 USB Cable
- 1 Grove - Gas Sensor O_2
- 1 CO_2 sensor
- 1 Temperature / Humidity sensor
- 3 Mini Self-Adhesive Breadboard
- 1 Jumper Wires M/M Pack of 65 mixed colours

Session 1: Mask use and breathability

This session involved the Technology Science Courses (CH) students, Chemistry subject, as it matches their Essential Learning Targets. Students carried out guided research on the retention of CO_2 and O_2 gases when wearing face masks in school, which had become mandatory to prevent the spread of COVID-19.

CO_2 and O_2 were monitored because of their importance in the buffering system of blood – maintenance of blood pH – as a small variation in the 7.35 – 7.45 range can lead to cell death, ultimately, including death.

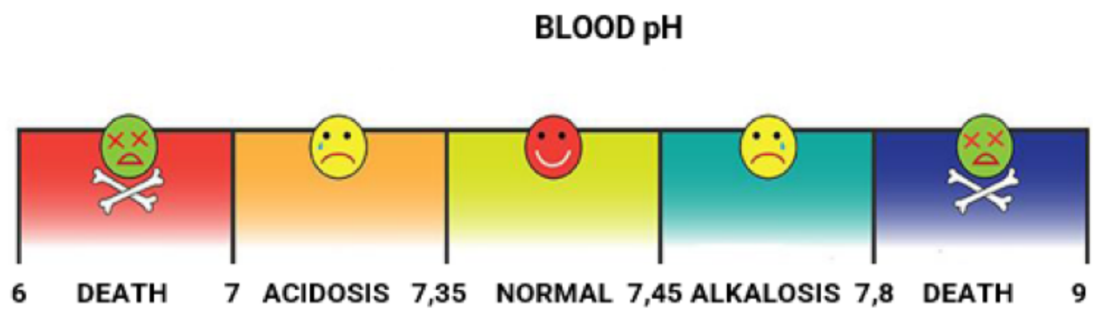


Figure 1 – Blood pH, adapted from https://www.scimed.pt/geral/dieta-alcalina-mitos-e-factos/

The reaction of CO_2 with water was the starting point to study the regulation of blood pH and to conclude that it is done by several buffer systems, being the most important one the conjugate pair H_2CO_3 (aq) / HCO_3^- (aq).

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$
$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$

Le Châtelier's Principle was revisited to analyse the equations and verify that when there is excessive CO_2 CO_2 retention in the lungs, it prompts the release of HCO_3^- HCO_3^- e H_3O^+ H_3O^+, causing an undesirable decrease in blood pH.

Having understood the way these gases bind to haemoglobin and the gas exchange process in the blood, everyday situations were considered

- Respiratory acidosis - Excessive accumulation of carbon dioxide in the blood

  and

- Respiratory alkalosis - Low carbon dioxide in the blood caused by rapid or deep breathing.

Are face masks responsible for CO_2 retention, as some symptoms referred to and attributed to the use of face masks, such as dizziness and headaches, are common to symptoms of acidosis?

To predict whether CO_2 levels would increase while wearing face masks, the students focused their research on the composition, manufacturing, and testing associated with face mask production. Surgical masks, type B2, were used, as they are commonly worn by students and teachers at our school. The study of the composition and manufacturing of these masks was carried out with internet research. The composition is essentially polypropylene and polyester, the outer layer being hydrophobic propylene.

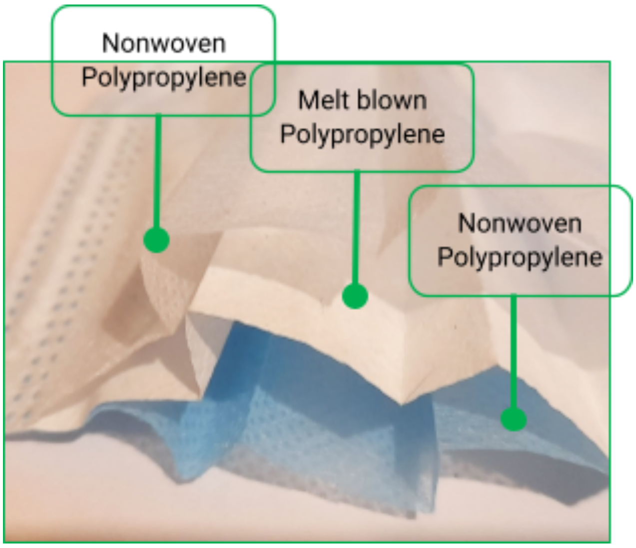


Figure 2 - section of a surgical face mask showing three layers of polypropylene

Nonwoven polypropylene is a fabric-like material made from staple and long fibres, and a polymer, usually polypropylene, randomly set and glued together by heat or pressure,
Melt blowing polypropylene is a conventional fabrication method of micro and nanofibers where a polymer melt is extruded through small nozzles surrounded by high speed blowing

gas. The porosity of the face masks was also looked into, and the outcome values ranged from 100 nm to 6 µm.

As the average molecular diameters of CO_2 (0.33 nm) and O_2 (0.15 nm) is much smaller than the porosity dimensions of the face masks, another research question was raised: Which other factors play a role in breathing problems while wearing a face mask? Therefore, temperature and relative humidity range variation was studied when wearing, or not, a face mask. Face masks must follow the EN 14683:2019 Standard, so bacterial filtration efficiency, air permeability of the face mask and microbiological load were tested (https://www.infarmed.pt/documents/15786/3584301/Mascaras+Versus+EPIs/733267cf-46d3-c102-bc19-bb5e1b6048a0)

Session 2: Developing a monitoring prototype

Using the Open-Source, Arduino platform, the Programming Computer Systems students (CP), grade 11, developed a prototype which allowed them to monitor the behaviour of certain variables (O_2, CO_2, Temperature and humidity) depending on wearing, or not, a face mask. They also verified the impact of these variables on the integrity of the face mask after the recommended time of use.

Arduino is an open-source electronic prototyping platform which provides hardware, software and different libraries that enable to program microcontrollers. Sensors were connected to the Arduino boards, thus having an interface with the computer to monitor the variables.

A Grove - Gas Sensor O_2 was used for measuring the *oxygen* variable, as schematized in the following figure.

.

Figure 3 - Grove - Gas Sensor O_2

This sensor has an electrochemical cell to test the oxygen concentration in air, which ranges from 0% to 25%.

A *Grove-VOC* and *CO_2 Gas Sensor* was used to test the CO_2, ranging from 400 ppm to 60000 ppm.

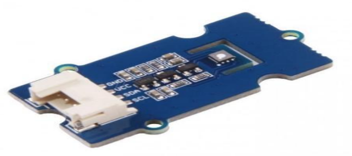


Figure 4 - *Grove-VOC* and CO_2 *Gas Sensor* (*SGP30*)

For the measurement of temperature and humidity, the DHT22 Temperature-humidity sensor was used. This sensor allows measuring humidity values from 0 to 100%, with an uncertainty of 2 to 5%, and temperature values from -40° C and 80° C, with an uncertainty of ± 0.5 °C.

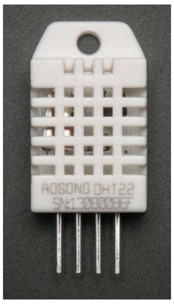


Figure 5 - DHT22 Temperature-humidity sensor

Libraries are a collection of C/C++ code files. Their contents may be changed in Arduino.

Project design. Simulation situation.

- Using *Tinkercad,* in a simulation situation, the circuits were assembled and the codes and the components were tested.

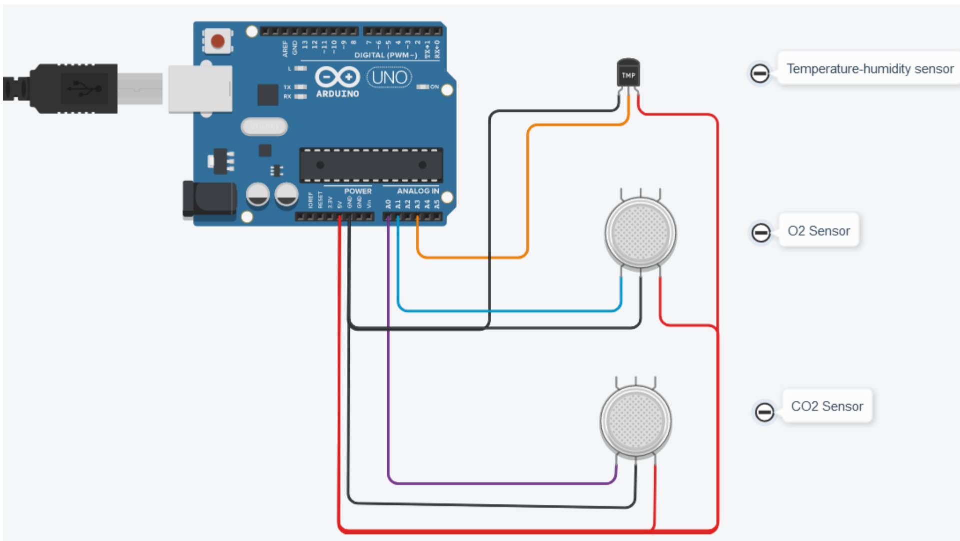


Figure 7 - *Tinkercad* Circuit

Hardware connection. Connecting virtual reality to reality.

❖ Following the project design, the components were connected using Arduino.

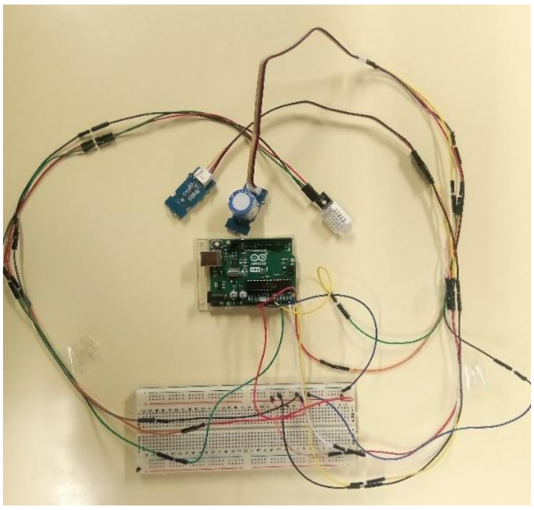


Figure 8 – Photo of the circuit assembly

Installing Arduino on your computer - Software | Arduino

Get the generated code by Arduino.

Code:

```
#include <DHT.h>
#include <sgp30.h>
#define DHTPIN A1          // what pin we're connected to
#define DHTTYPE DHT22   // DHT 22 (AM2302)

s16 error;
u16 tvoc_ppb, co2_eq_ppm;

const float VRefer = 3.3;     // voltage of adc reference
const int pinAdc   = A0;
int maxHum = 60;
int maxTemp = 40;

DHT dht(DHTPIN, DHTTYPE);

void setup() {
        Serial.begin(9600);
        dht.begin();

        while (sgp_probe() != STATUS_OK) {
                Serial.println("SGP failed");
                while (1);
         }
}

void loop() {
```

```
        float Vout =0;
        Vout = readO2Vout();

        // Wait a few seconds between measurements.
        float h = dht.readHumidity();
        float t = dht.readTemperature();

        // Check if any reads failed and exit early (to try again).
        if (isnan(h) || isnan(t)) {
                Serial.println("Failed to read from DHT sensor!");
                return;
        }

        error = sgp_measure_iaq_blocking_read(&tvoc_ppb, &co2_eq_ppm);

        Serial.print(h);
        Serial.print(";");
        Serial.print("\t\t");

        Serial.print(t);
        Serial.print(" C; ");

        Serial.print("\t");
        Serial.print(readConcentration());
        Serial.print(";");

        Serial.print("\t\t");
        Serial.print(co2_eq_ppm);
        Serial.println("ppm;");

        delay(100);
}

float readO2Vout(){
        long sum = 0;
        for(int i=0; i<32; i++) {
                sum += analogRead(pinAdc);
        }
        sum >>= 5;
        float MeasuredVout = sum * (VRefer / 1023.0);
        return MeasuredVout;
}

float readConcentration(){
        // Vout samples are with reference to 3.3V
        float MeasuredVout = readO2Vout();

        //float Concentration = FmultiMap(MeasuredVout, VoutArray,O2ConArray, 6);
        //when its output voltage is 2.0V,
        float Concentration = MeasuredVout * 0.21 / 2.0;
        float Concentration_Percentage=Concentration*100;
        returnConcentration_Percentage;
}
```

- Or transfer the Tinkercad code to the circuit. Although the code base is given, one must adjust it to the circuit.

Data collecting

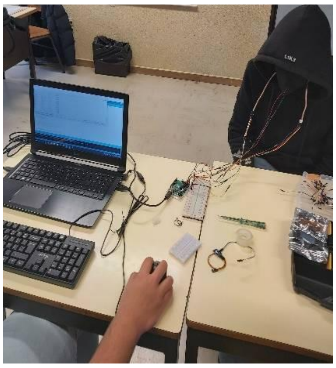


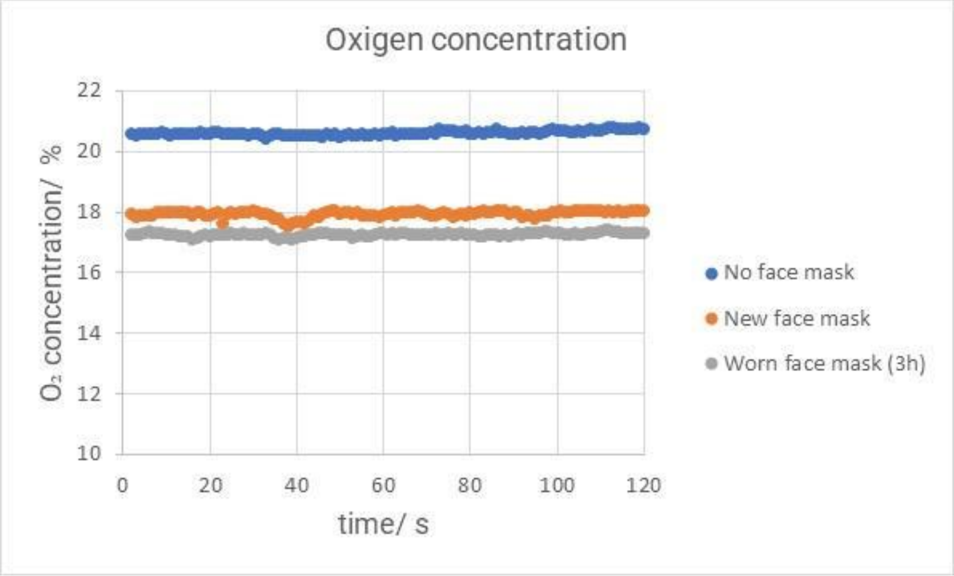
Figure 9 and 10 – photos of data collecting

Session 3: Data processing and analysis of the results (Chemistry and Mathematics)

The data collected by the sensors in session 2 were organised in an Excel table, and graphical representations were made. The students discussed the type of representation that could best answer the research problem question, having decided to use scatter diagrams where the variation of the variables over time was analysed. The data obtained for the variables under study were compared with the standard – no face mask wearing.

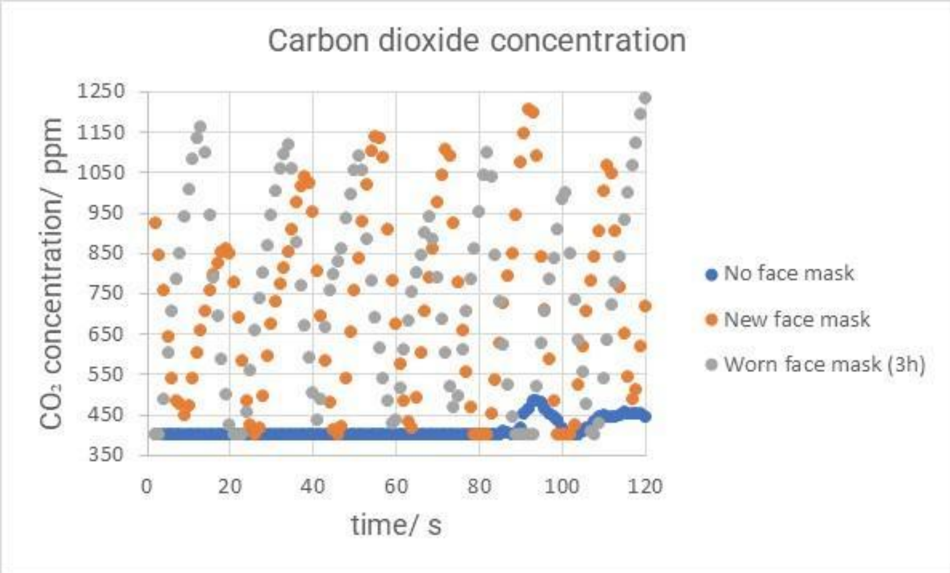
Oxygen - O_2

The oxygen concentration (in percentage) is lower when using face masks. However, this value remains practically constant over the time in which the data collection took place.



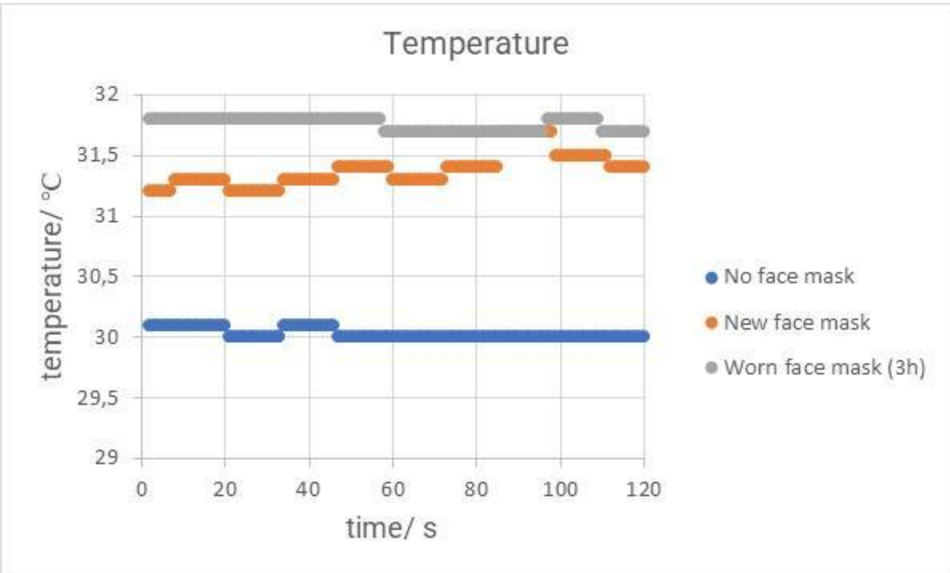
Carbon Dioxide - CO_2

The concentration of carbon dioxide, in parts per million (ppm), is practically constant while not wearing a face mask, matching the global average atmospheric carbon dioxide. The respiratory cycle is quite clear while wearing a face mask. The CO_2 concentration increases when you exhale, but this value decreases rapidly, which proves that face masks allow gas exchange.



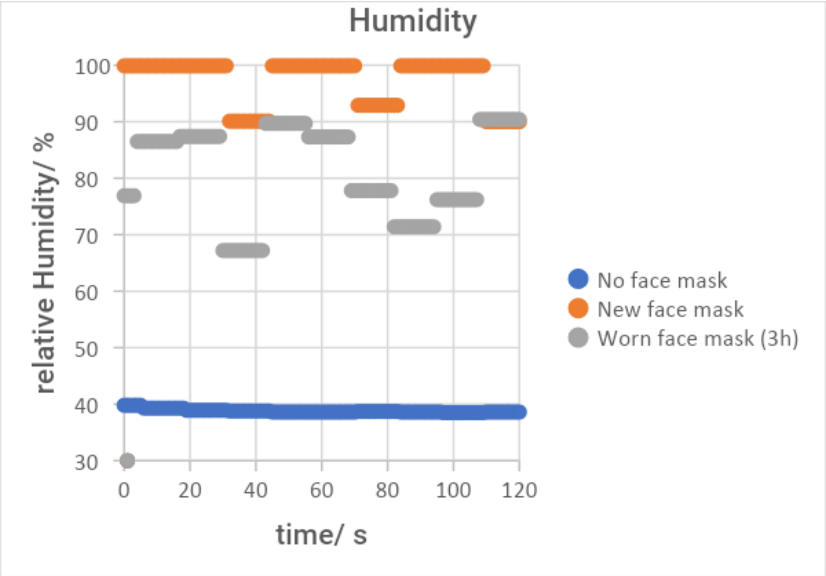
Temperature

On average, the body temperature is higher when wearing a face mask, and it remains practically constant. In the initial seconds, the body temperature rises when wearing a new face mask, but then it stabilises.



Humidity

The values obtained while wearing a face mask for the variable under study, Humidity, are quite different from when not wearing a face mask. Once again, it is possible to identify in the graph that the humidity increases when exhaling.



Conclusions

Face masks allow easy gas exchange, the concentration of CO_2 varies during the respiratory cycle and the concentration of O_2 remains constant. However, a decrease in O_2 levels, combined with higher humidity and body temperature, make breathing harder.

Learning outcomes

By promoting activities focused on the students' reality and interdisciplinary articulation, it certainly made the students' learning more meaningful.
Upon successful completion of the workshop, the students were able to:

- Explain the buffer systems and the blood pH regulation
- Set an Arduino Installation and Assembly
- Monitor variables with Arduino
- Apply the knowledge and skills acquired during the workshop to a real life situation
- Draw conclusions from the data collected showing scientifically based critical thinking.

6. UV radiation, how to protect ourselves?

When we talk about summer and the Algarve, in Portugal, we visualise sun, sea, beach ..., but we have to think about the caution we must have with sun exposure and ultraviolet radiation (UV). The frame of thought of the third workshop in Tavira run by teachers from Dr. Jorge Augusto Correia School was the precaution we should take to protect ourselves from UV radiation. We must consider that the sun radiation has benefits for humans, but also causes biological damage to the skin and eyes.

The problem question that served as a starting point was: Do sunglasses and sunscreens really protect our eyes and skin from UV radiation?

Curriculum Framework (Essential Learning Targets)

The student must be able to:

Chemistry

- ❖ Consolidate, deepen and broaden knowledge by understanding concepts, laws and theories that describe, explain and predict phenomena, as well as underlie its use in different situations and contexts;
- ❖ Analyse and interpret in relevant contexts physical and chemical phenomena with impact on technology, society and the environment;
- ❖ Use different audiovisual media and ICT in the observation and description of phenomena in specific contexts, do bibliographical research, present, question, justify and assess;
- ❖ Reveal responsibility, accuracy, autonomy, scientifically based critical thinking, strong sense of collaboration and curiosity.

Computer programming (PSI)

- ❖ Develop knowledge and skills for algorithms; programming languages; research work on the use of the components; Arduino Installation and Assembly;
- ❖ Increase collaborative production skills, focusing mainly on co-creativity and co-responsibility, which enhance open-mindedness for change;
- ❖ Develop skills for working with computer applications for specific learning and other training areas;
- ❖ Create habits and attitudes for lifelong learning as an essential condition for adjusting to new ways of communicating, which are rapidly expanding.

Grade Level: 11th
Estimated time: developed as a 2 - session workshop

Grade Level: 12th
Estimated time: developed as a 2 - session workshop

Materials & Technology (per group)

- 1 Computer
- 1 Arduino Uno R3 CH340 USB Cable
- 1 Ultraviolet (UV) sensor
- 3 Mini Self-Adhesive Breadboard
- 1Jumper Wires M/M Pack of 65 mixed colours
- Lab. Material (Sun Protection Cream)

Session 1: The solar radiation

This session was attended by students from the Chemistry (CH) courses, as it fits in with their specific core learning.

The concepts studied in the 10th grade of Physics and Chemistry were revisited:

- In the subdomain "Energy of electrons in atoms", in which the energies of photons are related to the frequency of light;
- In the subdomain "Chemical transformations", light is identified as the energy source for photochemical reactions and also a solar radiation filter; the ozone role in the stratosphere, interpreting the formation and the destruction of stratospheric ozone; the high reactivity of free radicals explain some of their effects on the atmosphere and on living beings, ageing is one of them;
- In the subdomain “Energy, thermal phenomena and radiation”, the content "Irradiance" was revisited.

The discussion of the solar radiation effects on human beings, its benefits and potential dangers, was the starting point for the research on the subject that included mechanical and chemical sun filters, their action and the meaning of the "sun protection index".

The students visited the IPMA (Portuguese Institute for the Sea and the Atmosphere), website at https://www.ipma.pt, and consulted the daily UV index value per city.

After having understood the basic concepts of sunscreens, the students proposed the production of a physical sunscreen cream.

The proposed cream production was used to follow the essential learning curriculum subdomain "Organic Chemistry", in which the students identified the organic compounds involved and the specific function of each one (hardener, moisturiser, emulsifier, protector...). After having researched several protocols for sun protection creams, the students chose to make the one using "natural" materials.

After having made adaptations from https://www.mafaldapintoleite.com/o-blog/protetor-solar-com-zinco , the students performed the following protocol:

Sun Protection Cream Protocol

In a thermal bath, mix:

Coconut oil - 30 g

Shea butter - 15 g

Sweet almond oil - 15 g

Beeswax - 15 g

Cocoa butter - 15 g

Figure 1 - material

After the mixture is homogeneous add:

Zinc oxide non-nano - 6 g

After cooling add a few drops of lavender essential oil.

Note: Wear mask and safety glasses when using the zinc oxide.

Non-nano zinc was used, so that it does not penetrate the skin and has the function of a physical protector, reflecting UVA and UVB rays.

Session 2: Measuring the UV radiation

To check whether the cream made in session 1 had UV protection, the Programming Computer Systems students of TGPSI, grade 11, developed, using the Open-Source platform, *Arduino*, a program to measure the UV. For this purpose, they used a UV sensor that uses a UV photodiode, capable of detecting radiation with wavelengths of 240-370 nm (which covers UVB and most of the UVA spectrum).

Project design. Simulation situation.

- Using *Tinkercad,* in a simulation situation, the circuits were assembled, and the codes and the components were tested.

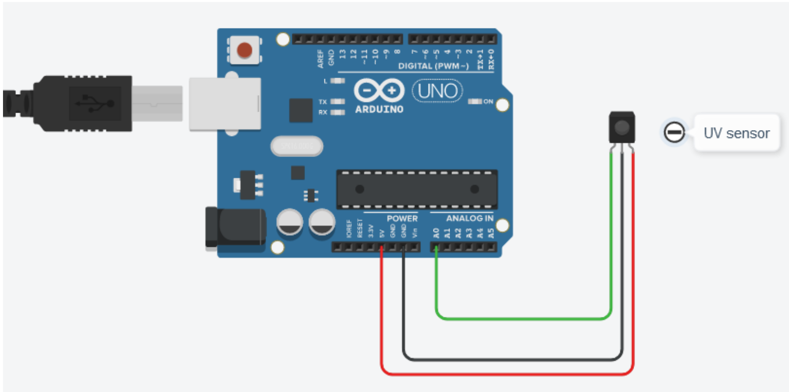


Figure 2 – *Tinkercad* simulation, UV sensor

Hardware connection. Connecting virtual reality to reality.

- Following the project design, the components were connected using Arduino.

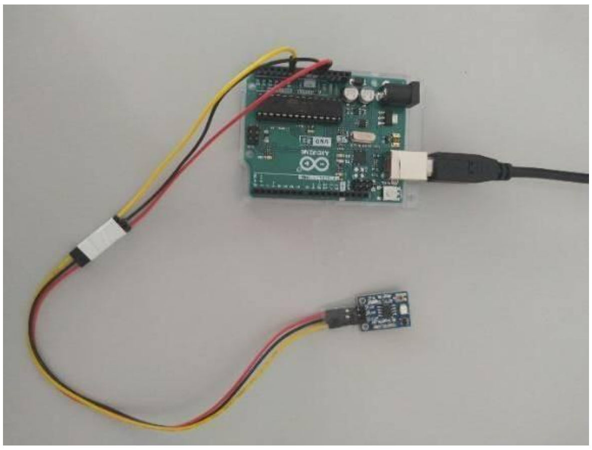


Figure 3 - Image of the circuit assembled with the UV sensor

Installing Arduino on your computer - Software | Arduino

- Get the generated code by Arduino

```
int sensorpin = A0, UVindex = 0;
float sensorValue;

void setup() {
        // put your setup code here, to run once:
        Serial.begin(9600);
        // pinMode(sensorpin, INPUT);
}

void loop() {
        // put your main code here, to run repeatedly:
        sensorValue = analogRead(sensorpin);
        // According to the reading defines the corresponding UV index
        if (sensorValue <= 10)                                    UVindex  = 0;
        else if (sensorValue > 10 && sensorValue <= 46)       UVindex = 1;
        else if (sensorValue > 46 && sensorValue <= 65)       UVindex  = 2;
        else if (sensorValue > 65 && sensorValue <= 83)       UVindex  = 3;
        else if (sensorValue > 83 && sensorValue <= 103)      UVindex  = 4;
        else if (sensorValue > 103 && sensorValue <= 124)     UVindex  = 5;
        else if (sensorValue > 124 && sensorValue <= 142)     UVindex  = 6;
        else if (sensorValue > 142 && sensorValue <= 162)     UVindex  = 7;
        else if (sensorValue > 162 && sensorValue <= 180)     UVindex  = 8;
        else if (sensorValue > 180 && sensorValue <= 200)     UVindex  = 9;
        else if (sensorValue > 200 && sensorValue <= 221)     UVindex  = 10;
        else                                                   UVindex  = 11;

        Serial.println(UVindex );

        delay(1000);
}
```

- Or transfer the Tinkercad code to the circuit. Although the code base is given, one must adjust it to the circuit.

Session 3: Data collection, analysis and conclusions

In this joint session, after the data collection and its analysis, the conclusion of the prepared work was carried out.

Data collection

The UV sensor was installed in a box, opaque to that radiation, with an opening in the upper part. The box gives stability to the sensor and allows the control of the variables, position and inclination towards the source (the Sun). The inclination used was approximately 30º, in order to obtain perpendicularity in the incidence.

Students started data collection by measuring the UV index:

- Directly, without filter covering the box opening;
- Covering the box opening with cellophane film;
- Covering the box opening with cellophane film, spread with the cream made at school;
- Covering the box opening with cellophane film, spread with the index 50 protective cream of a commercial brand;
- Covering the opening of the box with non-polarised sunglasses, with UVA and UVB protection;
- Covering the opening of the box with polarised sunglasses.

Figure 4 - materials used for data collection.

Data collection started at 12:00 and the exposure time was one minute for each test, recording every second.

The results presented reflect the average values of the protection index.

- For direct measurement, the average UV index is equal to 10;
- Measurement with cellophane film, the average UV index is equal to 10;
- Measurement covering the box with cellophane film spread with the cream made at school, the average UV index is equal to 1;
- Measurement covering the box with cellophane spread with the commercial protective cream, the average UV index is equal to 1;
- Measurement covering the box with non-polarised sunglasses, with UVA and UVB protection, , the average UV index is less than 1;
- Measurement covering the box with sunglasses, with UVA and UVB protection, polarised, the average UV index is less than 1;

Consulting IPMA website, the forecast for the day of data collection for the UV index was 8.

Conclusions

The following conclusions were obtained after discussion:

- The use of sunglasses with lenses with UVA and UVB protection is advised when the UV index is high. The polarisation of the lenses will not affect the values obtained for the UV index.
- Comparing the cream made at school and the commercial protective cream, index 50 protection, the UV indices obtained are similar.

The cellophane film was used because, among the materials tested, it presented the least decrease in the UV index and the easiest to spread the cream to obtain a uniform thickness.

Learning outcomes

All workshops were designed to:

- focus learning on students' accomplishments and
- promote interdisciplinary work or working between classes to enhance students' learning

Upon successful completion of the workshop, the students were able to:

- Explain the basic concepts of sunscreens
- Identify the specific function of the sunscreen organic compounds
- Set an Arduino Installation and Assembly
- Assemble circuits with a UV sensor
- Measure the UV radiation with an Arduino program
- Apply the knowledge and skills acquired during the workshop to a real life situation
- Draw conclusions from the data collected showing scientifically based critical thinking.

7. Basic electronics, home monitoring and control

The goal of the course was to give the students the base knowledge of electronics. The programme was developed and implemented by the Estonian partner school in the IoT project, Valga Gymnasium, as an extracurricular learning programme bridging a number of STEM subjects. By the end of the course, the students were capable of building their own „Smart House" using electronic tools.

Connection to the basic school and gymnasium curriculum

Technology and innovation
Creativity, collaboration skills and initiative in applying new technologies in various projects are developed within this course. The workshops that the students carry out themselves make the students value innovation and entrepreneurship. They also develop leading and organising skills.

Mathematics
Students develop overall problem-solving skills, including the ability of putting forward hypotheses, finding suitable strategies for testing, analysing the idea for solution and verify if the results are correct. At the same time, students improve their spatial thinking and their ability to use different measurement scales and units.

Physics
Planning experiments and carrying them through, using the scientific method. Collecting data and analysing it. Applying the knowledge acquired in electrical education solving problems (creating circuit diagrams, using semiconductors, electrical safety).

Grade Level: 9th – 12th

Estimated time: 1 course (21 x 75m in 5 days)

Materials & Technology

- Computer
- SparkFun Paper Circuits
- Different Arduino boards LilyPad E-Sewing, LilyMini ProtoSnap and Arduino MEGA 2560
- Raspberry Pi (first use mouse, keyboard and display), SD-card, NodeMCU
- Sensors: temperature DS18B20, temperature-humidity DHT22, 1 channel relay

Session 1: Basic knowledge of electronics

First, the students went over the basics of electronics and formed electric circuits with simple tools. The tools are paper, a light diode (LED), battery and conductive copper tape (Lessons).

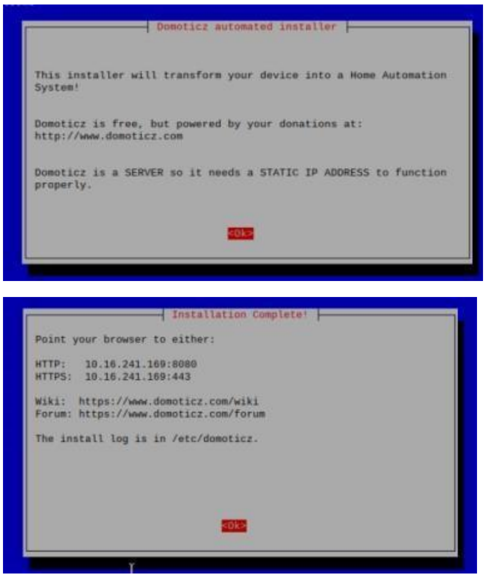
In the next step, we used the development board Arduino MEGA2560 and small size boards LilyPad E-Sewing and LilyMini ProtoSnap. In this step, students created the same circuits that they made on paper before. Now they are using the electronics components and Arduino IDE with Adfruit Makecode software. LilyPad E-Sewing and LilyMini ProtoSnap were meant for the students interested in sewing to make smart clothes (LilyPad, programming).

LilyPad E-Sewing and LilyMini ProtoSnap

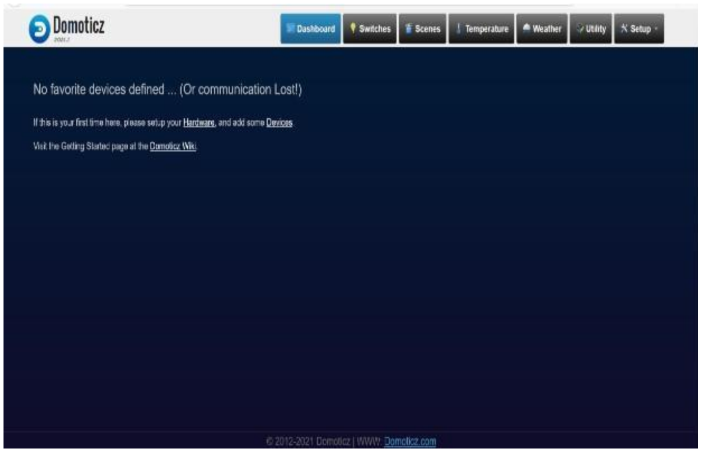
Simple paper circuits

Session 2: Smart House hardware and software

The main objective of this course was to build an open-source Smart House management system that doesn't depend on the manufacturer. As the first task, the students set up a minicomputer Raspberry PI. They installed the Raspberry PI operating system on a SD card and the remote management software (VNC, SSH). This way the minicomputer doesn't need a monitor, mouse, or keyboard to work (Raspberry PI manual).



Domoticz install



Domoticz smart home software

Using the remote management software, we installed the open-source Smart House software called Domoticz on the Raspberry PI. With this, we could control and monitor the server and the different sensors in the rooms (Domoticz manual).

To connect the Smart House sensor wirelessly, we used the NodeMCU ESP8266 WiFi development board. This enabled us to gather data within our local WiFi network and control the devices in the rooms, like the temperature and humidity sensors. We could start any device (like fan or a heating element) using relays and also control lighting and other electrical devices.

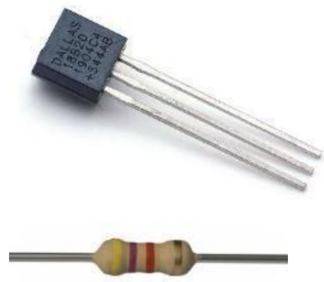
Raspberry PI Smart House server

NodeMCU ESP8266 WiFi Development Board

The sensors that we used in this course are Raspberry PI monitoring tools (manual), 1 channel relays, temperature sensor DS18B20 and temperature-humidity sensor DHT22.

1 channel relay (Manual)

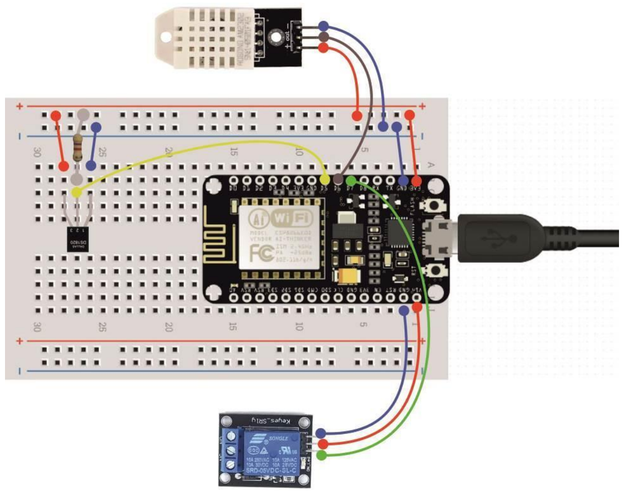
temperature-humidity DHT22 Manual



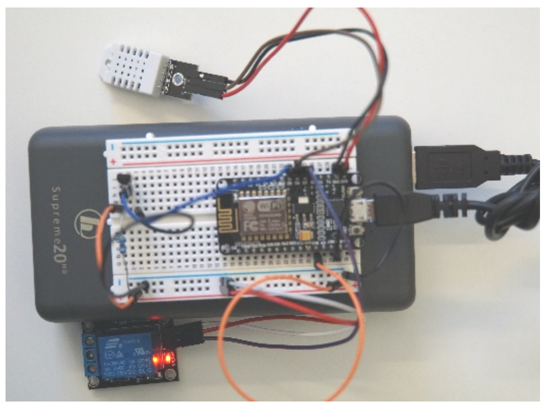
temperature DS18B20, 4,7k ohm resistor (Manual)

Session 3: Smart Home monitoring and management

To connect the sensors, we used a NodeMCU board and made a circuit diagram according to the instructions in the sensor manuals.



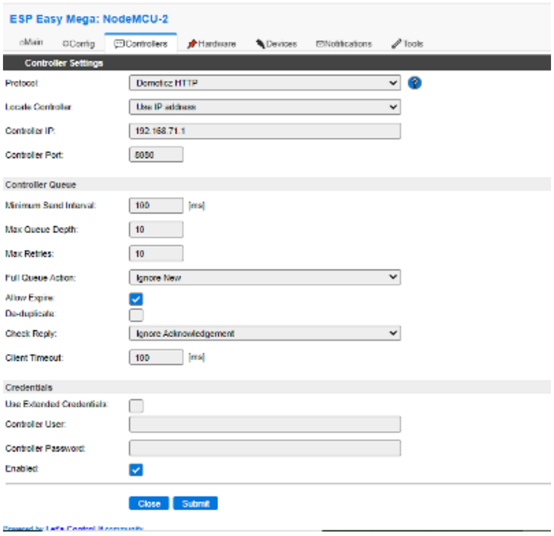
Wireless sensors schematic diagram



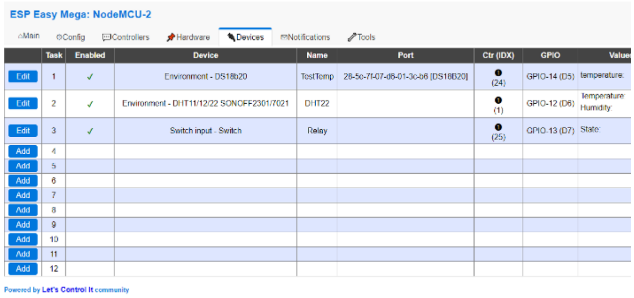
Wireless Sensors

After making the diagram, we set up the WiFi development board with the program ESPEasy, so the Smart House server could communicate with the sensors wirelessly. For that, we installed the NodeMCU ESPEasy software on the development board. (ESPEasy manual).

After installing the ESPEasy software, we first set up all the connections to the Smart House Server (Raspberry PI Domoticz) and after creating the connections we configured connections of the sensors. Up to 15 sensors can be connected to one WiFi development board.



Configure connection to Smart Home server



Connected sensors

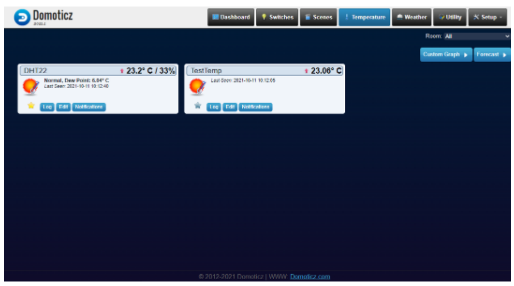
Afterwards, we configured the sensors in the Smart House server. We created an entry for each sensor in the “Hardware” window of the program, after which the new sensor appeared in the “Devices” window.

As the last task, we needed to connect the Smart House sensor entry with the wireless sensor. Every Domoticz device has its own Idx number which needs to be added to the WiFi Development board program ESPEasy, in the Idx field “send to controller”. With the right configuration, the sensor data will appear in the Smart House program.

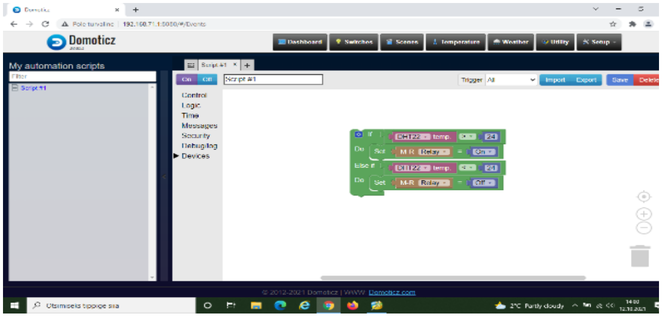
Add hardware (devices) to Smart Home

Available sensors on Smart Home

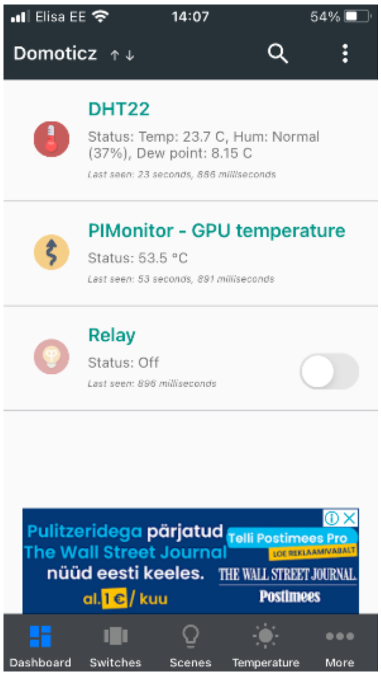
Smart Home PC App dashboard



Smart Home temperature sensors



Simple blocky script



Android/iOS monitoring and control

With the open-source Smart House program, you can connect a lot of sensors, lamps, and devices from different manufacturers. It is possible to automate the system writing scripts into the program. The scripts can be programmed in different coding languages (Python, Lua, dzVets, Blocky). (Domoticz wiki)

Learning outcomes

- The students that completed the course acquired the basic knowledge of electronics and prototyping.
- They have an overview and skills to perform simple scale builds on Raspberry Pi.
- They can create data transfer between a smart device and the Smart House server.
- The students can see an opportunity to solve technological problems and improve everyday life through smart work and practical actions.

8. Raspberry PI MQTT standard messaging protocol and Unity Real-Time Development Platform

The goal of the course is to give the students the base knowledge of electronics. The programme was developed and implemented by the Estonian partner school in the IoT project, Valga Gymnasium, as an extracurricular learning programme bridging a number of STEM subjects. By the end of the course, the students are capable of building their own Unity game that uses real-time data.

Connection to the basic school and gymnasium curriculum

Technology and innovation

Creativity, collaboration skills and initiative in applying new technologies in various projects are developed within this course. The workshops that the students carry out themselves will make the students value innovation and entrepreneurship. They'll also develop leading and organising skills.

Mathematics

Students develop overall problem-solving skills, including the ability of putting forward hypotheses, find suitable strategies for testing, analyse the idea for solution and verify if the results are correct. At the same time, students improve their spatial thinking and their ability to use different measurement scales and units.

Physics

Planning experiments and carrying them through, using the scientific method. Collecting data and analysing it. Applying the knowledge acquired in electrical education solving problems (creating circuit diagrams, using semiconductors, electrical safety)

Grade Level: 9th – 12th

Estimated time: 1 course (21 x 75m in 5 days)

Materials & Technology

- Computer
- Raspberry Pi
- NodeMCU ESP8266 WiFi development board
- MQTT server software
- Sensors: temperature DS18B20, temperature-humidity DHT22, 1 channel relay
- MQTT Explorer
- Unity Real-Time Development Platform
- Visual Studio Code

Session 1: Installing Raspberry PI and MQTT standard messaging protocol

Installing Raspberry PI

As the first task, the students set up a minicomputer Raspberry PI. They installed the Raspberry PI operating system on a SD card and the remote management software (VNC, SSH). This way the minicomputer doesn't need a monitor, mouse, or keyboard to work (Raspberry PI manual).

MQTT standard messaging protocol

MQTT is an OASIS standard messaging protocol for the Internet of Things (IoT). It is designed as an extremely lightweight publish/subscribe messaging transport that is ideal for connecting remote devices with a small code footprint and minimal network bandwidth. MQTT today is used in a wide variety of industries, such as automotive, manufacturing, telecommunications, oil and gas, etc.

Before installing the MQTT broker to our Raspberry Pi, we need to update the operating system.

Terminal command: sudo apt update and sudo apt upgrade

Install the Mosquitto software. Run the following command to install Mosquitto alongside its client software: sudo apt install mosquitto mosquitto-clients.

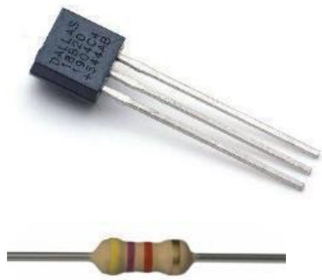
Now have the Mosquitto MQTT broker up and running on your device. You can verify that it is installed and running by using the command: sudo systemctl status mosquitto.

Session 2: NodeMCU ESP8266 WiFi development board and sensors

The sensors we use in this course are: 1 channel relays, temperature sensor DS18B20 and temperature-humidity sensor DHT22.

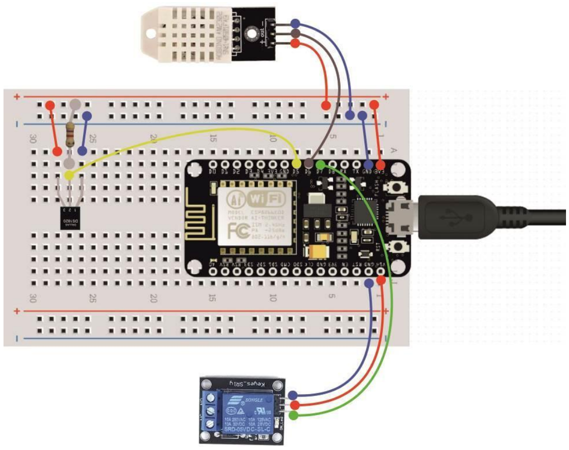
1 channel relay (Manual)

temperature-humidity DHT22 Manual

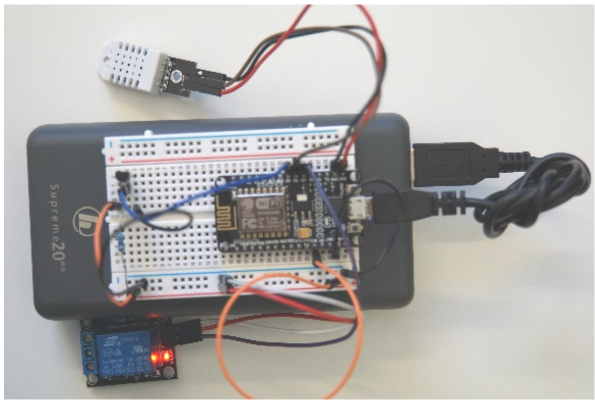


temperature DS18B20, 4,7k ohm resistor (Manual)

To connect the sensors, we used a NodeMCU board, and made a circuit diagram according to the instructions in the sensor manuals.



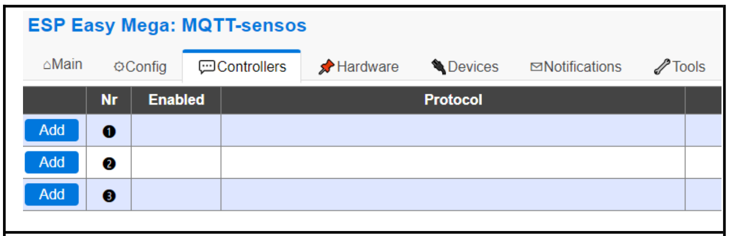
Wireless sensors schematic diagram



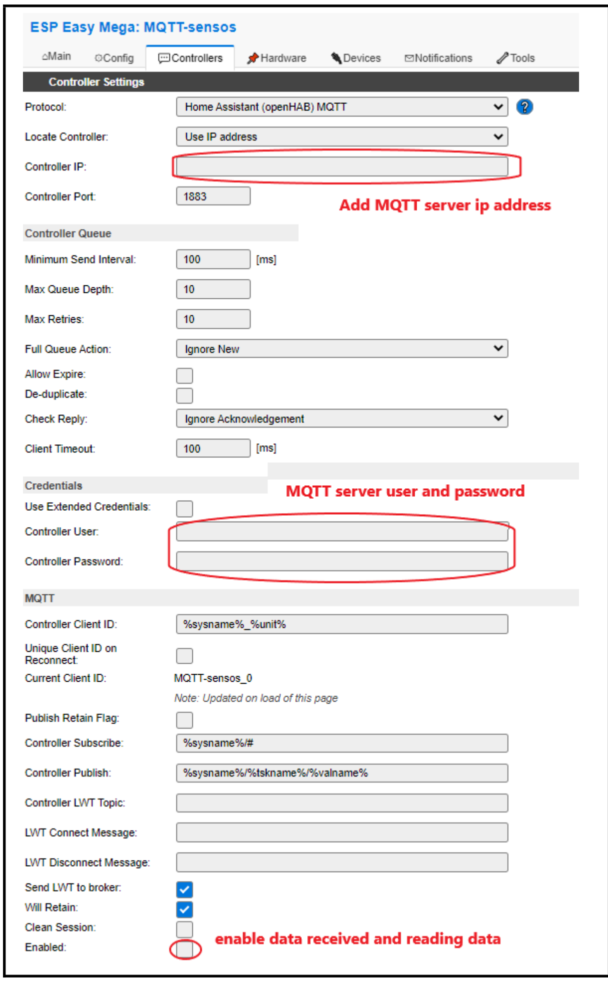
Wireless Sensors

After making the diagram, we set up the WiFi development board with the program ESPEasy, so the MQTT server could communicate with the sensors wirelessly. For that, we install the NodeMCU ESPEasy software on the development board. (ESPEasy manual).

After installing the ESPEasy software, we first set up all the connections to the MQTT server and after creating the connections we configure connections of the sensors. Up to 15 sensors can be connected to one WiFi development board.



Connect MQTT standard messaging protocol



Protocol: Select Home Assistant (openHAB) MQTT,

Controller IP: add Raspberry PI MQTT server IP address

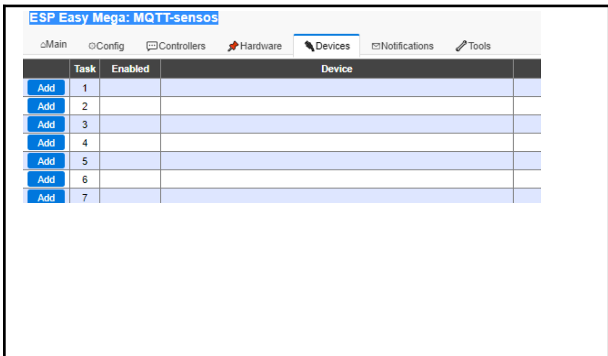
Controller user: Raspberry PI username

Controller password: Raspberry PI password

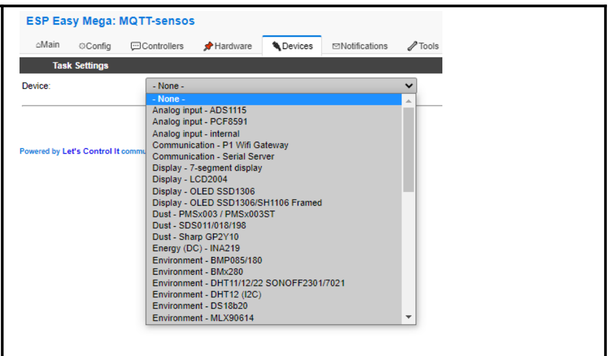
(default raspberry pi username: pi and password: raspberry)

Enable: make to box

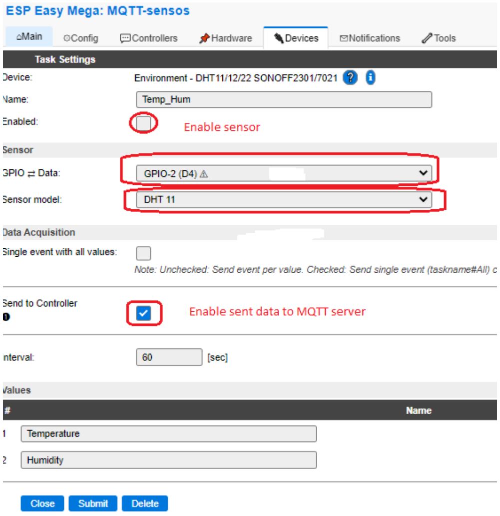
Add sensor to NodeMCU



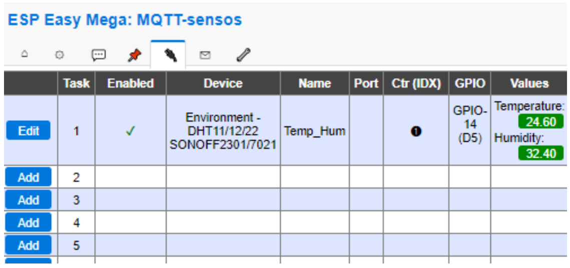
Adding the sensor



Choosing which sensor to connect (DHT22)

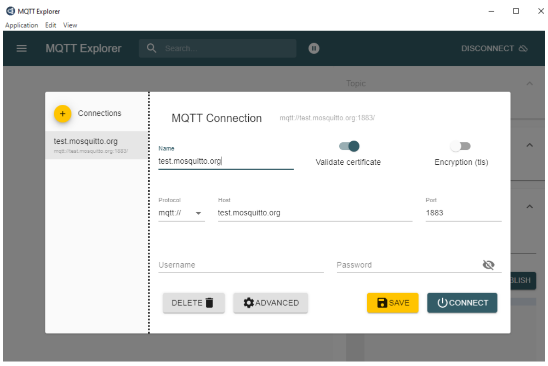


Setting up DHT22 sensor

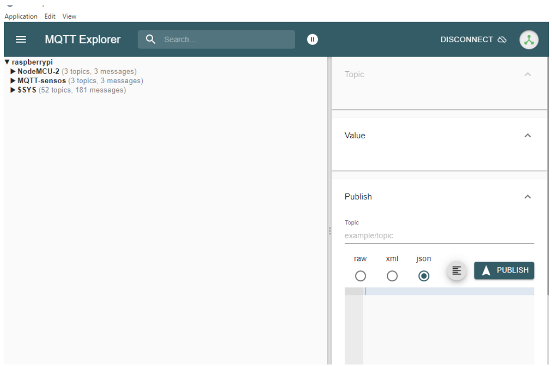


DHT22 sensor sending data

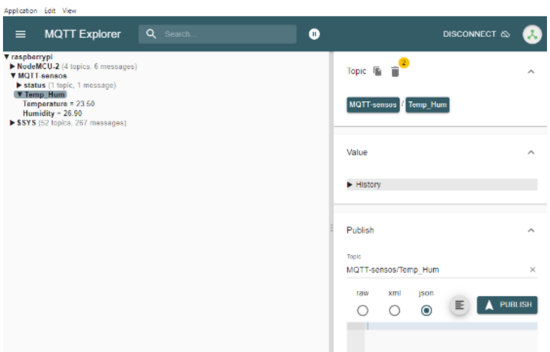
To validate the connection between the development board and MQTT server, we downloaded the program MQTT-Explorer (http://mqtt-explorer.com/). There's a choice between installable and a portable version. We downloaded the portable version and ran it.



Enter the MQTT server data



Devices connected to the MQTT server



NodeMCU data we have added

If temperature and humidity data is displayed correctly, it means we've succeeded in connecting the DHT22 sensor to the MQTT server. Now we'll add 1 channel relay and temperature DS18B20 sensor following the manual above.

Session 3: Unity Real-Time Development Platform

First, we'll install Unity software into our computer. For this we'll go to the Unity website https://unity.com/, choose **Get Started** from the Menu and choose a suitable software plan. The different choices include a paid version for teams and a free version for individual use.

We will choose the Individual Person version and press **Get Started**. In the next window, we'll choose the downloadable program ***Download Hub for Windows Beta*** or ***Download for Windows***. The difference between the two is that the et Beta version is still in the testing phase. We will download the Windows version. Save *UnityHubSetup.exe* to our computer and start the program.

To work with the Unity software, we must activate the licence. The Unity Licence can be activated by making an user account and logging in.

Next, we need to install Unity. For this, we choose the menu **Install**, then press **ADD**, choose a suitable version and install it to our computer. Note that this process might take some time.

After the installation and running the program, we'll choose Projects from the menu and add a new project clicking the button **NEW**. We choose project type, for example **3D**, and name the project while also choosing a location for it in the computer.

Now we are able to use the Unity software.

Learn Unity - Beginner's Game Development Tutorial
https://www.youtube.com/watch?v=gB1F9G0JXOo

Session 4: Connect MQTT to Unity

The next task is to connect the rooms made in Unity to the existing sensors. In our project, we use 2 sensors and one switch (relay).

So that the room made in Unity could communicate with our Raspberry Pi server, we need to add our Project to the M2Mqtt library (https://github.com/CE-SDV-Unity/M2MqttUnity). After downloading the M2MqttUniti project (Download ZIP), we unpack the .zip file into our computer.

Next, we need to add to our catalogue Assets\CE\scripts in the game two new C# scripts: mqttReceiver.cs and mqttController.cs.

Into the MqttReceiver.cs script, we add the library we previously unpacked. The contents of the file
M2MqttUnity-master.zip\M2MqttUnity-master\Assets\M2MqttUnity\Examples\Scripts\M2MqttUnityTest.cs

Next, we will open the mqttController.cs we made and add the following code:

```
using System.Collections;
using System.Collections.Generic;
using UnityEngine;

public class mqttController : MonoBehaviour
{
   public string nameController = "Controller 1";

   public mqttReceiver _eventSender;

  void Start()
  {
   _eventSender.OnMessageArrived += OnMessageArrivedHandler;
  }

  private void OnMessageArrivedHandler(string newMsg)
  {
   Debug.Log("Event Fired. The message, from Object " +nameController+" is = " +
newMsg);
  }
}
```

As a last task, we need to display the NodeMCU sensor data inside our game. For this, we will add GameObject'i TextMeshPro (TMP). TextMeshPro (TMP) is part of Unity but needs to be activated: right-click in Hierarchy--> 3D Object --> Text-TextMeshPro. The first time, a window will ask to Import TMP Essentials. We will again open the mqttController.cs script and add TMPro classes (using TMPro;) and OnMessageArrivedHandler function (this.GetComponent<TextMeshPro>().text=newMsg;).

As the final result, the real temperature and moisture data are displayed in our 3D project.

Following the manual, we will connect the 3D object we made in Unity with the MQTT server.

MQTT Client in Unity
(https://workshops.cetools.org/codelabs/CASA0019-unity-mqtt/index.html?index=..%2F..index#5)

Learning outcomes

- The students that completed the course will have the basic knowledge of electronics and prototyping.
- Students have an overview and skills to perform simple scale builds on Raspberry Pi.
- Students can create data transfer between a smart device and the Smart House server.
- Students see an opportunity to solve technological problems and improve everyday life through smart work and practical actions.

9. VR Escape Room

The goal of the course is to give the students the base knowledge of electronics. The programme was developed and implemented by the Estonian partner school in the IoT project, Valga Gymnasium, as an extracurricular learning programme bridging a number of STEM subjects. By the end of the course, the students are capable of building their own Unity game that uses real-time data.

It will be useful to have completed the course of Raspberry PI MQTT standard messaging protocol and Unity Real-Time Development Platform.

Connection to the basic school and gymnasium curriculum

Technology and innovation

Creativity, collaboration skills and initiative in applying new technologies in various projects are developed within this course. The workshops that the students carry out themselves will make the students value innovation and entrepreneurship. They'll also develop leading and organising skills.

Mathematics

Students develop overall problem-solving skills, including the ability of putting forward hypotheses, finding suitable strategies for testing, analysing the idea for solution and verifying if the results are correct. At the same time, students improve their spatial thinking and their ability to use different measurement scales and units.

Physics

Planning experiments and carrying them through, using the scientific method. Collecting data and analysing it. Applying the knowledge acquired in electrical education solving problems (creating circuit diagrams, using semiconductors, electrical safety)

Grade Level: 9th – 12th

Estimated time: 1 course (21 x 75 min in 5 days)

Materials & Technology

- Computer
- Raspberry Pi, NodeMCU ESP8266 WiFi development board
- Sensors: temperature DS18B20, temperature-humidity DHT22, 1 channel relay

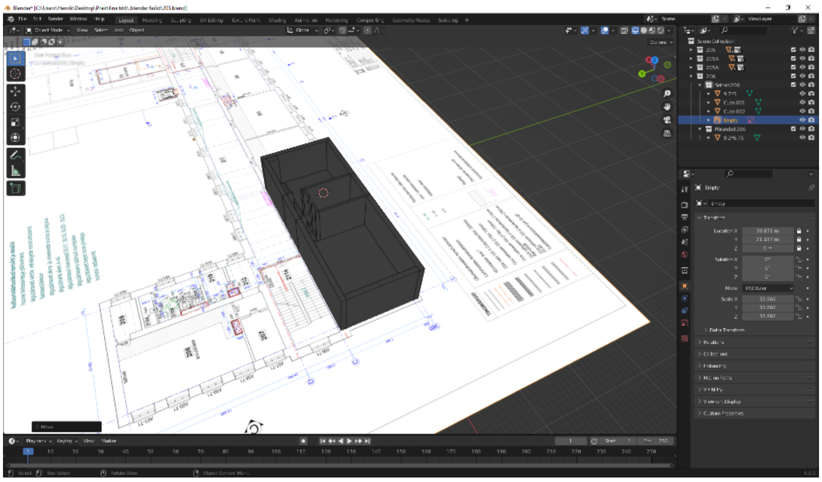
Software

- Raspberry Pi – Mosquitto MQTT broker software (https://mosquitto.org/)
- PC software - MQTT Explorer (http://mqtt-explorer.com/)
- NodeMCU software - ESPEasy (https://github.com/letscontrolit/ESPEasy)
- PC software - Unity Real-Time Development Platform (https://unity.com/)
- PC software - Visual Studio Code (https://code.visualstudio.com/)
- PC software – Blender (https://www.blender.org/)

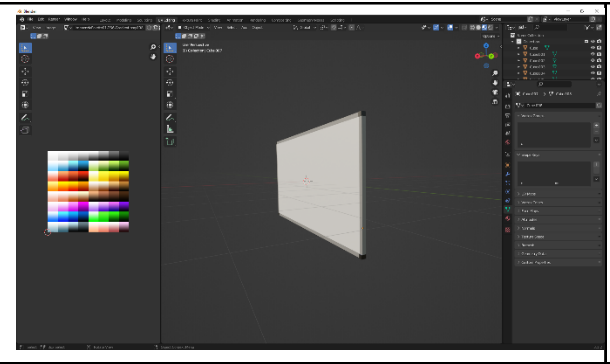
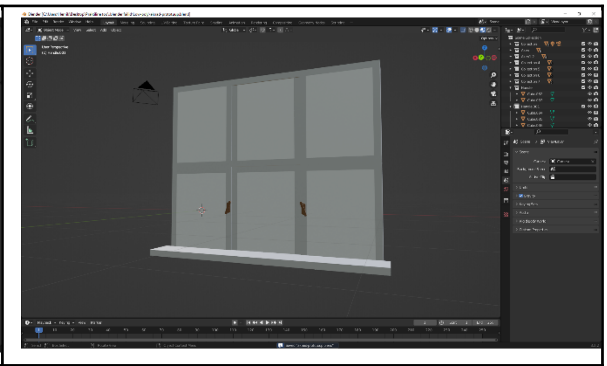
Session 1: Blender 3D modulations

The goal is to create rooms in virtual reality which would be as similar as possible to the rooms existing in the real world. A more detailed modelling and similarity with the real world is needed for creating the virtual reality objects, so the user would have the feeling of being in a real environment.

First, we will measure the existing rooms. If we already have the room plans in the right scale, we will use these. Here, we have room plans in jpg-format and we can start modelling existing rooms on top of them.



To 'build' the walls of the rooms, we use the cubes in the rooms, which will create walls. Then, we cut the door and window openings into it and colour the rooms. Next, we will model room details, like windows, doors, chairs, tables, whiteboards. Here's the instruction video for modelling objects: https://www.youtube.com/watch?v=sW_NnFgIiso0

	
Modelling the whiteboard	Modelling the window

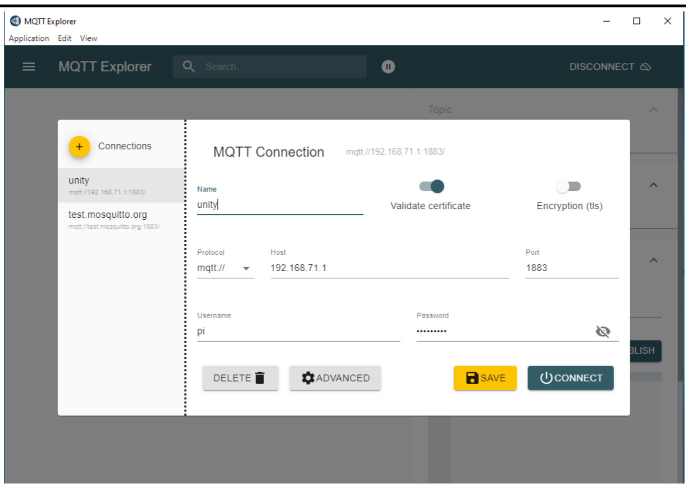
Session 2: Raspberry PI smart house Domoticz and MQTT broker

We take a configured Raspberry PI that has the Smart House program Domoticz installed.

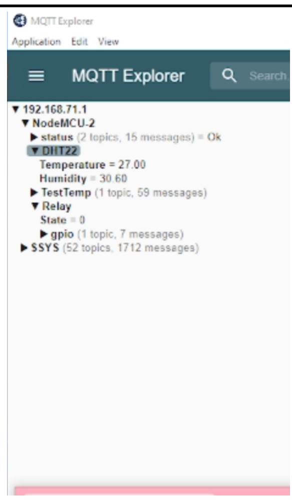
Next, we'll install the Mosquitto MQTT broker software on the Raspberry PI and set up the program (password, port, user name). If all done correctly, we'll start the Mosquitto MQTT broker software.

To ensure everything works, we'll install the MQTT Explorer on the computer. We start the program and fill out the fields. NAME field requires the name of the connection, HOST field requires the MQTT broker server IP address, USERNAME field: MQTT broker username and on PASSWORD field we will write MQTT broker's password.

Next, we will save and click the button CONNECT, which will connect the program to the server.



Setting up MQTT Explorer



MQTT Explorer working

Session 3: Unity

After starting Unity and creating a new project, we will first set up the VR Rig and Camera

1. Package Manager(Project Settings) - - - > Enable Preview Packages
2. Package Manager - - - > XR Interaction Toolkit
3. XR Plug-in Management(Project Setting) - - - > PC(Oculus + Windows Mixed Reality) + Android(Oculus)
4. Create Empty Parent Object named - - - VR

   Create Empty Object named - - - VR Rig

   Add XR Origin.cs

   Tracking Origin Mode - - - Floor

5. Create Empty Parent Object named - - - Camera offset
6. Create camera, name it VR Camera and put it in Camera offset

   Set Clipping Planes Near - - - 0.1

   Add Tracked Pose Driver component

   Set Pose Source Center Eye - HDM Reference

7. Set XR Rig

   Camera Floor Offset Object - - - Camera offset

   Camera Game Object - - - VR Camera

8. Add Snap Turn Provide (Device-based) for looking around with the controller joystick

   Set turn amount - - - 15 (recommended)

   Set activation timeout - - - 0.2 (recommended)

9. Add Teleportation Provider to teleport around

   You must add Teleportation Area to any object to make it work

   Teleportation Anchor teleport you to the centre of object, but the Area teleport will teleport you to the place which you currently had your teleportation ray pointed at.

Hands and Hand Presence

1. Create Empty Objects Left Hand and Right hand and drag it to Camera Offset Object
2. Add XR Controller.cs to left and right hand

   Set Controller Node for right hand to right hand and same to the left hand

3. Add XR Direct Interactor.cs script
4. Add Sphere Collider component and set its radius to 0.2 to 0.4
5. Create Empty Object Hand Presence (set Transform 0,0,0)

   Add HandPresence.cs script, which comes with HandPresence+LocomotionController.unitypackage

6. Import VR Controller Model.unitypackage and Oculus Hands.unitypackage (downloadable from the Web)

7. Drag all controller prefabs to Controller Prefabs in Hand Presence.cs script
8. Oculus Hands >>> Prefabs

    Drag Right hand Model to Hand Model Prefab in Hand Presence.cs script

    NB! Hand models are purple. To fix this you must create new material (best is grey colour). Then double-tap the Right Hand Model and drag new material to it.

9. Drag Hand Presence Object to Project Assets and delete one from the scene
10. Duplicate Hand Presence and name one Right Hand Presence and the other one Left Hand Presence and set Left Hand Presence Hand Model Prefab to Left Hand Model.
11. Set Right Hand Presence Controller Characteristics to Controller+Right and same for the Left Hand Presence in Hand Presence.cs script
12. Drag Right Hand Presence to Right Hand Model Prefab in XR Controller(Device-based).cs script and same for the left one.
13. Create Animator Controller and call it Right Hand Animator
    Drag it to Animator component, to Controller in Right Hand Model located in Oculus Hands Prefabs

14. Select created Animator Controller and go to Windows - - - Animation - - - Animator
    Click Parameters and create two new float values, one Grip and other one Trigger.

15. Create Blend Tree in Animatorm by right clicking the background and selecting Create State. Double click it to go inside it.
16. Inside Blend Tree select 2D Freedom Cartesian for Blend Type and make sure that first parameter is Grip and the second is Trigger
17. Add four Motion Field:

    Set first field pos X and Y to 0

    Set second field pos X to 0 and Y to 1

    Set third field pos X to 1 and Y to 0

    Set fourth field pos X and Y to 1

18. Drag Take 001 to first field
    Drag r_hand_pinch_animation to second field

    Drag r_hand_fist to third field and fourth field

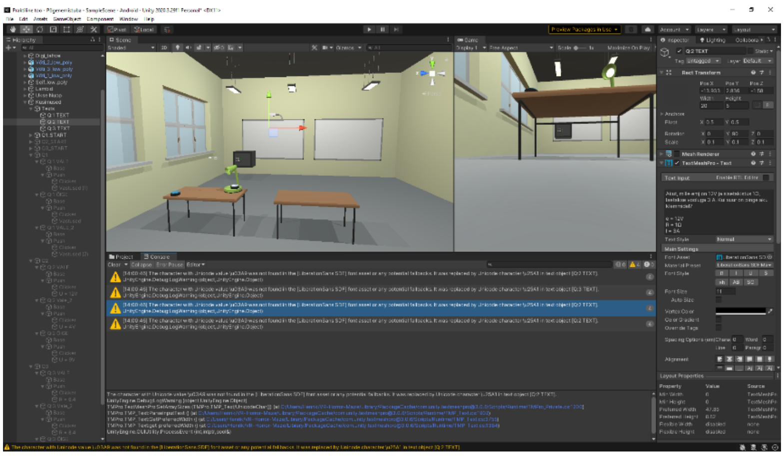
19. Duplicate Right Hand Animator and name second one to Left Hand Animator and repeat #13.
20. Set Hide Controller on Select in Left and Right hand XR Direct Interactor.cs script to hide hands when holding something.

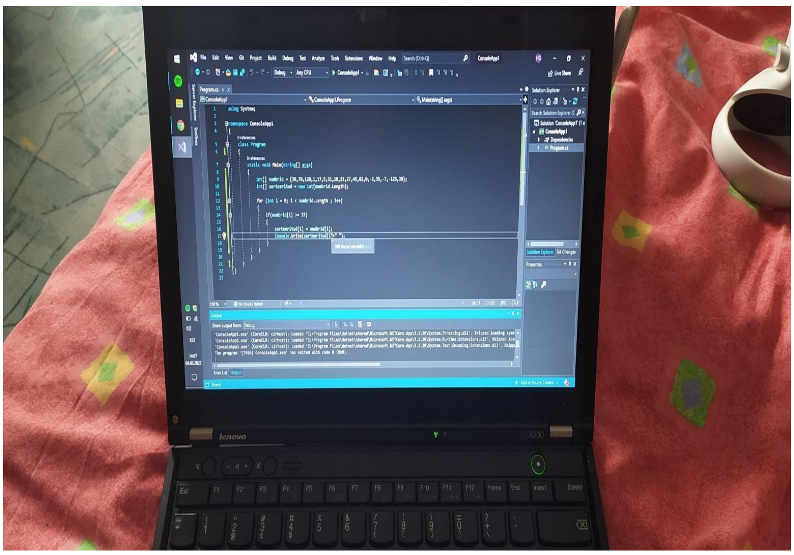
Grabbing Items

1. Create any 3D object

   Add Rigidbody component

   Add XR Grab Interactable.cs script





Session 4: Unity temperature sensor and relay

After importing the rooms and setup, we will connect IoT devices with Unity. So we could connect IoT devices to the VR project, we will need the MQTT Broker (the server), which we set up in session 2.

To connect with the MQTT broker, we will download from CE-SDV-Unity/M2MqttUnity web page the necessary components (https://github.com/CE-SDV-Unity/M2MqttUnity). After this, we will unpack MqMqttUnity.zip and copy the folders M2Mqtt and M2MqttUnity into our Unity project folder called Assets.

For the Smart House data to reach Unity, we will need to make some changes in the script. The script we need to change is located at Assets >MQTT>M2MqttUnity>Scripts> M2MqttUnityTest.cs.

First, we will add the rows to turn the switch on and off:

```
    public void LylitiSisse()
        {
            client.Publish("NodeMCU-2/Relay/gpio/13",
System.Text.Encoding.UTF8.GetBytes("1"), MqttMsgBase.QOS_LEVEL_EXACTLY_ONCE,
false);
            Debug.Log("Test message published");
            AddUiMessage("Test message published.");
        }

        public void LylitiV2lja()
        {
            client.Publish("NodeMCU-2/Relay/gpio/13",
System.Text.Encoding.UTF8.GetBytes("0"), MqttMsgBase.QOS_LEVEL_EXACTLY_ONCE,
false);
            Debug.Log("Test message published");
            AddUiMessage("Test message published.");
        }
```

(NodeMCU-2/Relay/gpio/13 the smart house relay NodeMCU GPIO value 0-off ja 1-in)

Next, we will add the smart house temperature to the script:

```
  protected override void SubscribeTopics()
        {
            client.Subscribe(new string[] { "M2MQTT_Unity/test" }, new byte[] {
MqttMsgBase.QOS_LEVEL_EXACTLY_ONCE });
            client.Subscribe(new string[] { "NodeMCU-2/DHT22/Temperature" }, new byte[] {
MqttMsgBase.QOS_LEVEL_EXACTLY_ONCE });
        }
```

```
protected override void DecodeMessage(string topic, byte[] message)
 {
    string msg = System.Text.Encoding.UTF8.GetString(message);
    Debug.Log("Received: " + msg);
    temperatuurtext(msg);
    StoreMessage(msg);
    if (topic == "M2MQTT_Unity/test")
    {
       if (autoTest)
       {
          autoTest = false;
          Disconnect();
       }
    }
 }
```

(we add the row temperatuurtext(msg))

And lastly, we will add the lines that will display the VR project's temperature component GameObject TextMeshPro.

```
public void temperatuurtext(string temp)
 {
    temptekst.GetComponent<TextMeshPro>().text= temp;
    Debug.Log(temp);
 }
```

This is how we can connect different smart house IoT sensors to Unity.

Learning outcomes

- The students that have completed the course will have the basic knowledge of electronics and prototyping;
- They'll have an overview and skills to perform simple scale builds on Raspberry Pi;
- They can create data transfer between a smart device and the Smart House server;
- The students see an opportunity to solve technological problems and improve everyday life through smart work and practical actions.

Chapter III

Resources and tools

Chapter III: Resources and tools

In the process of designing and testing different IoT workshop scenarios we have discovered a number of valuable resources and tools which are worth presenting to other teachers who may need concrete ideas on how to venture into this STEM field.

Accordingly, this closing chapter aims at facilitating implementation of IoT workshops in the context of school education. It goes beyond the above selection of workshop scenarios to provide ideas where to find other resources and tools for the classroom, both concrete technologies of educational value and pedagogical ideas.

IoT technologies for educational purposes

- LUMA Centre Finland. Available online: https://www.luma.fi/en/centre/ (accessed on 29 June 2022)
- NTNU's Resource Centre for STEM-Education. Available online: https://www.ntnu.edu/skolelab (accessed on 29 June 2022)
- Estonian Centre for Engineering Pedagogy. Available online: https://www.ttu.ee/en/?id=150200 (accessed on 29 June 2022)
- NSTC. Available online: https://www.whitehouse.gov/ostp/nstc/ (accessed on 29 June 2022)
- Labdisc Portable STEM Lab. Available online: https://global.boxlight.com/ (accessed on 29 June 2022)
- LabQuest® 2. Available online: https://www.vernier.com/product/labquest-2/ (accessed on 29 June 2022)
- Cooking Hacks by Libelium. Available online: https://www.cooking-hacks.com/mysignals-sw-ehealth-medical-biometric-complete-kit (accessed on 29 June 2022)
- UMI-Sci-Ed Platform. Available online: https://umi-sci-ed.cti.gr/umiscied/?q=content/welcome-umi-sci-ed-platform (accessed on 29 June 2022)
- Tiles IoT Inventor Toolkit. Available online: https://www.tilestoolkit.io/ (accessed on 29 June 2022)

- Scimodo – The IoT Platform for Science Education. https://www.scimodo.com/ (accessed on 29 June 2022)
- Hardwario Kits. https://www.hardwario.com/ (accessed on 29 June 2022)
- Arduino Platform. https://www.arduino.cc (accessed on 29 June 2022)
- Innovatoorium. https://sites.google.com/view/innovatoorium/avaleht (accessed on 29 June 2022)

Research on IoT in education

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- He, J.S.; Ji, S.; Bobbie, P.O. (2017). *Internet of things (iot)-based learning framework to facilitate stem undergraduate education*. In Proceedings of the SouthEast Conference, Kennesaw, GA, USA; pp. 88–94
- Kusmin, M.; Saar, M.; Laanpere, M. (2018). *Smart schoolhouse—Designing IoT study kits for project-based learning in STEM subjects*. In Proceedings of the Global Engineering Education Conference (EDUCON), Tenerife, Spain; pp. 1514–1517

- Mavroudi, A.; Divitini M.; Gianni, F.; Mora, S. (2018). *Designing IoT applications in lower secondary schools*. Department of Computer Science Norwegian University of Science and Technology Trondheim, Norway. Available online: http://simonemora.com/papers/conference/2018_EDUCON.pdf (accessed on 29 June 2022)

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- Fauquex, M.; Goyal, S.; Evequoz, F.; Bocchi, Y. (2015). *Creating peopleaware IoT applications by combining design thinking and user-centered design methods*, IEEE 2nd World Forum on Internet of Things (WFIoT), pp. 57-62

- Miller, M. (2015). *The Internet of things: How smart TVs, smart cars, smart homes, and smart cities are changing the world*. Pearson Education

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