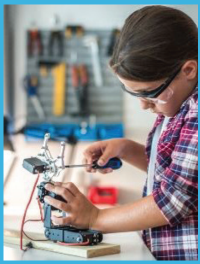
CONSTRUCTION AND PROGRAMMING the robot

METHODOLOGY FOR TEACHING ESTEAM in I-VET schools using robots to involve I-VET students in the learning process, to develop transversal skills



LEARNING OF CONTENT based on hands-on experiences

ROBOTS

ISBN 978-80-87049-09-9

APRIL 2018

TO GROW I-VET students' transversal skills

and key competences such as digital competences, entrepreneurship, critical thinking, problem solving learning to learn.. using ESTEAM concepts

Co-funded by the Erasmus+ Programme of the European Union

Skills ROBots BOosTs

ROBOTS BOOSTS SKILLS

MEET THE TEAM

RObots BOosTs Skills was funded by the European Commission under ERASMUS+ Action: KA2-Cooperation for innovation and the exchange of good practices.

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LETTER FROM THE EDITOR

THE GUIDE IS focused on using robots like an innovative tool to enhance students' motivation towards the study of ESTEAM subjects, improve their basic and transversal skills, art design and promote gender equality.

The guide will contain:

A Robotics Multidisciplinary Educational Framework involving the robotic systems, based on the following steps:

1. The construction of the robot
2. Programming the robot
3. Learning of content based on hands-on experiences
4. Methodology for teaching ESTEAM in I-VET schools using robots to involve I-VET students in the learning process, to develop transversal skills (i.e., creativity, innovative and crtiical thinking, problem solving, team working, resilience, self-confidence, etc.), to integrate women and promote gender equality in ESTEAM subjects.
5. Effective use of robots and transnational cooperation to promote the ESTEAM knowledge

THE GUIDE contributes to the priority "Further stengthening key competences in VET" through more effective, innovative teaching methods.

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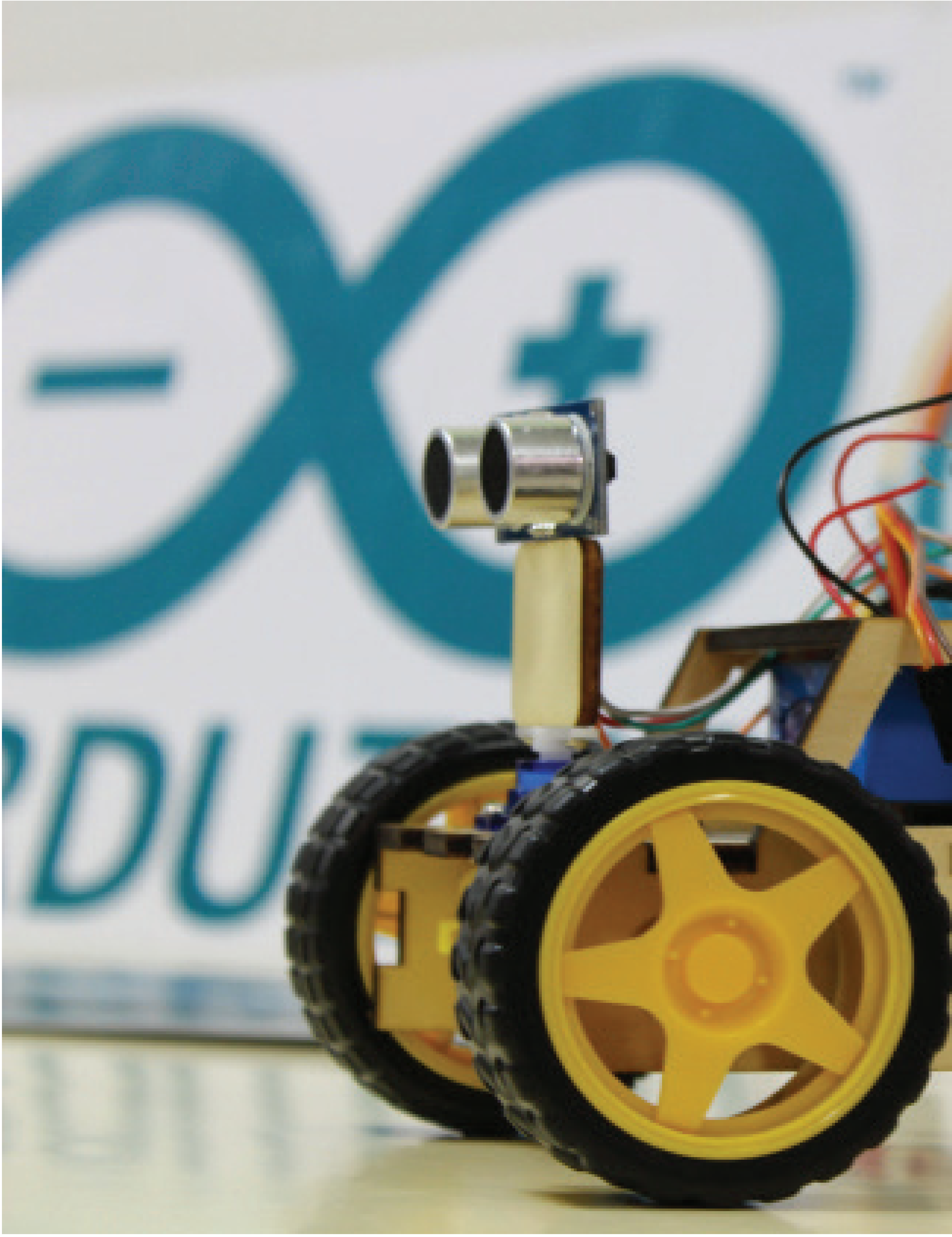
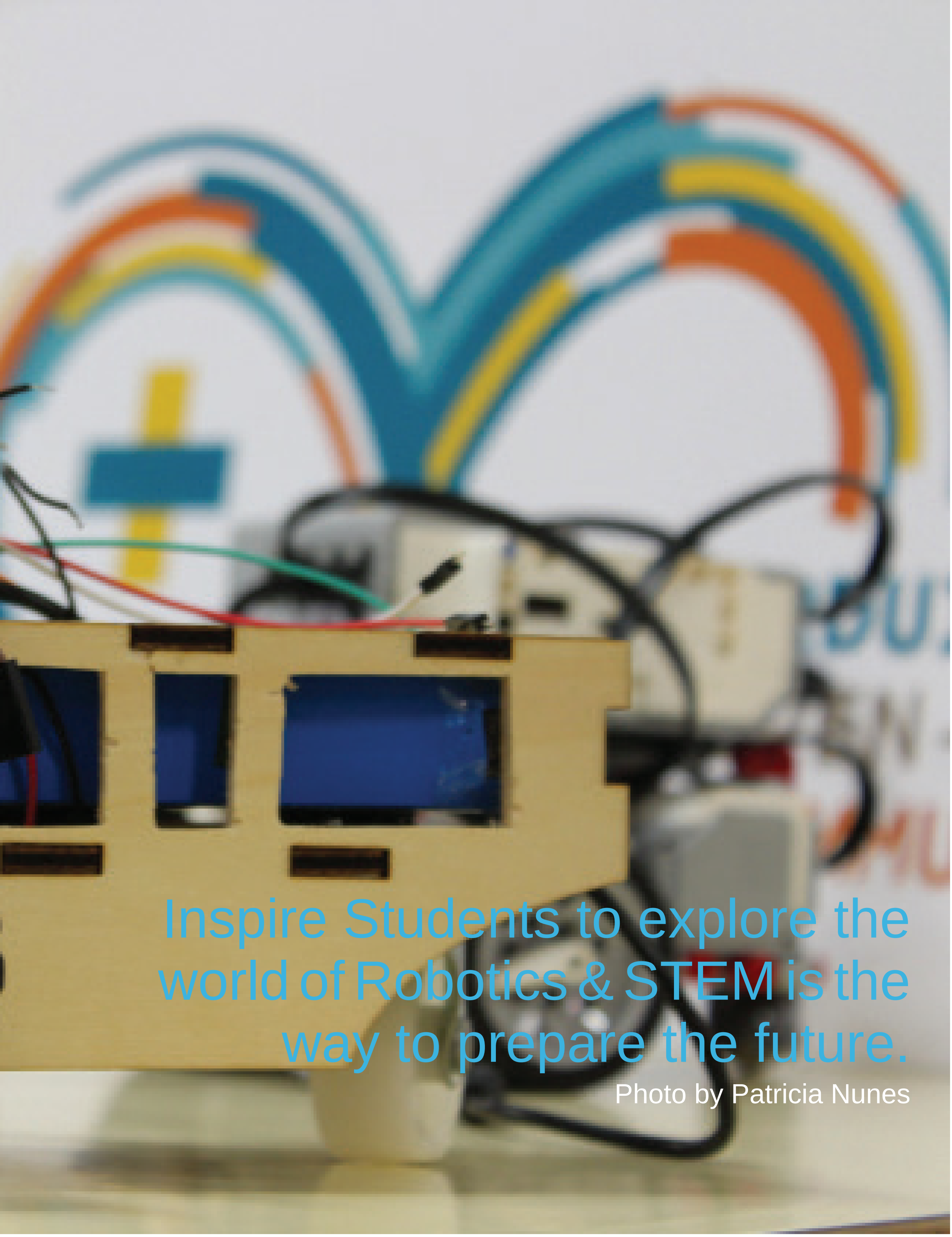




Inspire Students to explore the world of Robotics & STEM is the way to prepare the future.

Photo by Patricia Nunes

It's hard to imagine that having a robot as a friend is a future many of us would desire. But human nature may pave the way for these relationships. And it may be inevitable.

ESTEAM

WHAT IS ESTEAM?

We should ask ourselves; what is the world we are going to leave to our youth? They will have to carry it through and work with whatever we leave them. We believe that the most important thing to alter is to encourage youth that a change is possible no matter the odds. We would like to stress the importance of ESTEAM fields; Engineering, Science, Technology, Environment, Art and Mathematics, in the sense that what drives a young individual is what they should study because in that fashion the world will experience a different, positive, flow. The premise of the fields of ESTEAM is creativity, visionary, innovations and development.

ESTEAM is an acronym of 6 specific disciplines;

- E-Engineering
- S-Science
- T-Technology
- E-Environment
- A-Art
- M-Mathematics

PARTS

Engineering

Engineering is the application of scientific knowledge and mathematical methods to practical purpose of the design, analysis or operation of structures, machines or systems.

Science

Science is a systematic enterprise that builds and organizes knowledge in the form of testable explanations and predictions about the universe. Science is imperative to acknowledging the world that surrounds us not how we want it to be but how it is.

Education is changing right now. Technology and expanded knowledge of the learning process have already resulted in a metamorphosis of the classroom and of teaching methods.

Technology

Technology is the collection of techniques, skills, methods and processes used in the production of goods or services or in the accomplishment of objectives, such as scientific investigation. Technology could be presented as a vast, deep ocean of human experience.

Environment

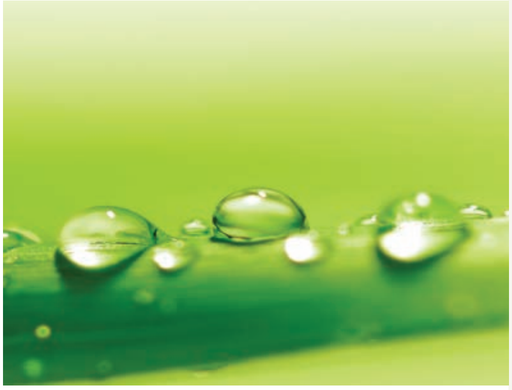
Let's explain the term "Environment" and how a lot of people confuses it with "Ecology".

Ecology is a scientific field of biology that studies the interactions among organisms and their environment. Being a biological science, it is closely related to the living matter (although there are exceptions).

It studies subjects such as: Biodiversity, Population ecology (populations, their sizes and migrations), Food webs, Animal behaviour, Coevolution, Molecular Ecology…

Subjects such as: Recycling, Waste management, Renewable resources, Nature friendly materials, Air pollution etc. are NOT Ecology but "Environmental science/ Environmental protection".

"Environmental science" is an interdisciplinary field which includes many scientific fields (Biology,



Geology, Geography, Chemistry, Geophysics, Meteorology and even Engineering).

So, to make it clear, Ecology, as a scientific field of Biology, is part of the larger Environmental science. But Environmental science is not a part of Ecology nor its synonym.

Art

Art is a diverse range of human activities in creating visual, auditory or performing artefacts (artworks), expressing the author's imaginative or technical skill, intended to be appreciated for their beauty or emotional power.

Mathematics

Mathematics is the study of such topics as quantity, structure, space and change.

Remember:

Students learn by doing. Experiential activities are critical to their success.

When possible, encourage active, hands-on participation rather than demonstrations or lectures.

Design activities that allow the students to experiment and problem-solve.

Students, especially those from under-represented groups, will make the connection between themselves and ESTEAM through real world examples.

Show Students how ESTEAM disciplines are part of and relate to their everyday experiences.

Allow students the freedom to choose curriculum themes and activities that interest them most.

Note for Girls:

Recognize that girls interested in science, technology, engineering, and math are more likely to pursue careers in the ESTEAM fields if they are exposed to women role models.

COLLABORATIVE WORK IN THE ESTEAM CLASSROOM

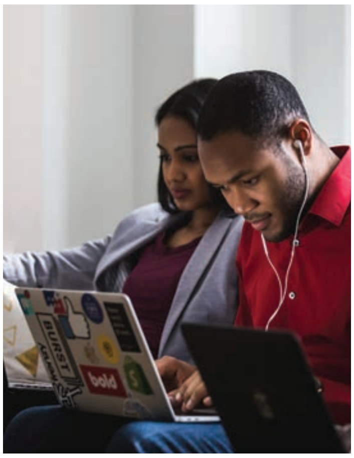
The question that we often ask ourselves as ESTEAM teachers is how important is the collaborative work for the learning effectiveness. The first consideration we need to keep in mind is that working in group improves the students' **engagement and participation**, mainly due to their active role played in the lessons. Students are longer required to be silent spectators, on the contrary they are encourage to actively participate in classroom. Confucius said: "I hear and I forget, I see and I remember, I do and I understand" and this is probably the slogan that most summarizes the importance of the active learning methodology.

We think that there are also other important reasons to promote the team work.

Working in group implies for students move out of their own "comfort zone" in order to interact with other people, expressing opinions and exchanging ideas. It is worth noting that all these activities not only improve students **communications skills**, but they also involve other benefits. Discussing and interacting with the others helps everyone **to identify their own limitations and their own potentialities**, therefore it increases the awareness on their own weak points and they own strengths.

"Alone we can do so little, together we can do so much."

HELLEN KELLER



Why Collaborate? *Collaboration helps you to create a team-oriented workforce.*

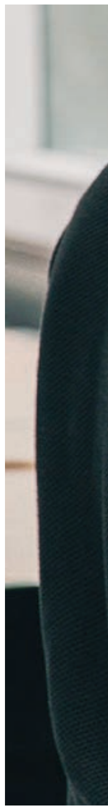
Provide Leadership Support

Set Ground Rules

Although the benefits described till now are matters of paramount importance for the effectiveness of teaching, we think that from an ESTEAM perspective it should be consider that working in group boosts the **creativity**. Basically, the concept is that more ideas you hear, more ideas you generate. When you work in group, the final flow of ideas is not simply the sum of the ideas of the individual, but it is enormously greater, because every thought is positively contaminated by the thoughts of others. The analogy we prefer to figure out the production of ideas when working in groups is that a thought is similar to a corn seed. Interaction with others is the environment that makes it explode and become a pop-corn.

However, despite the many advantages described above, teachers know that one of the most common risk is that only a few students participate in the proposed activity, while the others tend to do little or nothing. How to avoid this risk and make the team activities effectiveness? Trying to answer this question, we find the short manual written by Anne Jolly (http://www.bham.wednet.edu/studentgal/onlineresearch/oldonline/mod8team.htm) very interesting and usefull. Here the "Seven Student Teaming Tips and Tools" she proposes to help teachers establish successful student teams.

Step 1: Organize and plan for teamwork	
	Decide on team sizes that will maximize project success.
	Decide which students will be on each team.
	Be sure students have the prerequisite skills they need for doing the required tasks.
	Be sure the needed materials are available, organized, and set up for easy access.
Step 2: Introduce a teamwork rationale (Why are we working in teams?)	
	Help students consider the value in working together.
Step 3: Establish a purpose for the teams' work (What is our purpose?)	
	Clarify the function of the student "engineering" teams.
	Define the goal and outcomes for the teamwork.
	Verify that students understand the lesson's purpose ask them to explain to you what their team is expected to accomplish.
Step 4: Establish teamwork procedures (How will we do the work?)	
	Guide teams in setting norms.
	Giving students experience with interaction skills through multiple teaming experiences will build more successful teamwork during STEM lesson activities.
	Use self-assessments to help students improve teamwork skills.
Step 6: Monitor teamwork	
	Regularly monitor teams and provide productive feedback.
Step 7: Check teamwork progress	
	Regularly collect student feedback on how effectively groups are working.
	Leave enough time at the end of class to debrief.



Establish Realistic Expectations & Clarify Goals

Organize the Process Build Trust

The ESTEAM method is a way of teaching based on the idea of educating students in the six different competences, it is an interdisciplinary and applied approach.

WHAT

THE ESTEAM METHOD

RATHER THAN TEACHING THESE COMPETENCES SEPARATELY, THE METHOD CONSISTS OF THE BLEND OF THE SIX AND IT AIMS AT CREATING AND SUPPORTING A COLLABORATIVE LEARNING ENVIRONMENT WITH REAL-WORLD APPLICATIONS. THE ESTEAM METHOD TEACHES STUDENTS CRITICAL THINKING AND FOCUSES ON THE REAL-WORLD APPLICATIONS OF PROBLEM SOLVING.

The ESTEAM is extremely important, since it helps to take teaching from that traditional perspective in which the teacher is a mere transmitter of content. With the ESTEAM, the disciplines of this areas are no longer seen as elementary in the school. The learning becomes lighter and more effective.

ESTEAM teachers apply methodologies and present problems that must be solved. Students plan and develop projects. If something goes wrong, a positive attitude is adopted: students are motivated to discover where the error is, rather than a negative assessment, which encourages perseverance and self-criticism.

The best way to ensure future success and longevity it is to make sure that students are well versed in these subjects. Building a solid STEM foundation through a well-rounded curriculum is the best way to ensure that students are exposed to math, science, and technology throughout their educational career.

UNDERSTAND WHAT IS THE ESTEAM METHOD

Students are extremely curious and impressionable, so instilling an interest at an early age could spark a lasting desire to pursue a career in any of these fields. By the time a student is ready to enter the workforce, they must have enough knowledge to make invaluable contributions to ESTEAM industries. It is also important that schools have an ample amount of teachers who are experts in ESTEAM, and these subjects should always be considered as high demand subjects. Teachers who follow an alternative route to teacher certification are at an advantage to teach in an ESTEAM field if they majored in one, or are transitioning from a ESTEAM-related career. Every teachers that have studied chemistry, biology, physics, calculus, engineering, or any other ESTEAM subject, they will be a great asset to your school. (Administrators, you count too: many advanced degrees for education leadership focus on subjects in ESTEAM, particularly education technology. Since administrators set the tone for schools and entire districts, it's important that they care about advancing ESTEAM awareness and proficiency too).

TEACHERS ARE ASKED to have lessons that are engaging and relevant, cross-curricular, focus on 21st century skills, differentiate learning, incorporate non-fiction reading and writing and provide an authentic assessment of their students understanding. ESTEAM education is all about and Defined ESTEAM strives to bring this type of learning to each teacher and student in a school.

“[Science] is more than a school subject, or the periodic table, or the properties of waves. It is an approach to the world, a critical way to understand and explore and engage with the world, and then have the capacity to change that world...”

—President Barack Obama,
March 23, 2015

The importance the ESTEAM for the teachers

ESTEAM is not just a new subject for schools requiring more entries in the school time table. Rather, it is a way to integrate different subjects into classes, thus transforming the way the classes are planned and activities assigned to students. Although all the members in the education system have to agree and promote ESTEAM, the teacher is the leader and starting point in applying it at class.

In several ways, and in a world that's constantly changing some teachers have taken a step forward in their methodologies. Maybe they are actively participating in some innovation project, or they are taking courses on new methodologies, or simply they observe their colleagues moving ahead of traditional classes, and this prompts them to innovate as well. As a result, It is probable that many teachers are already following many of the ESTEAM principles.

These teachers will benefit from learning and fully integrating into ESTEAM. They will find a established community of colleagues willing to discuss about. And will have a more complete guideline to help plan the classes.

As in every job, business and field of knowledge, the members and people within any organization, must progress and take on new methods, technologies and procedures. That's the progress, actually. Teachers are no different. They are expected to get to know new advances and trends in education. ESTEAM and others are new topics that have large amount of innovation and new methodologies behind. Perfecting teaching can be achieved in several ways, one of them being the knowledge about innovation and about what other colleagues do.

Some key elements directly point to teachers as the initiators and managers of activities.

● Organize and arrange groups of students to perform experiments, demonstrations or research. This requires a ultimate responsible for the suitability of group membership and a constant look over.

● Mentoring students. Students are likely to succeed in STEAM if

they have a mentor who to look up to. Either the teacher himself or some eminent person could play this role to the student.

● Engagement and motivation. Students have to be aware and engaged in the activities they are going to perform. And they should be stimulated to solve the problem that drives the lesson. The Teacher has to spread enthusiasm among the whole group

● Although one of the central ideas is the creativity from students and their active role in class, the teacher still needs to verify the eligibility of the proposals and ongoing work. The goal is to integrate science, maths, engineering, arts, environment and technology. A carefully planned experiment or activity can bring together lots of concepts from different subjects whereas a bad designed activity will bring poor results.

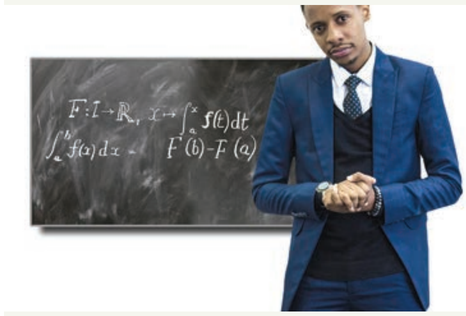
Combining several subjects when solving problems may require help from different Teachers, mainly when the difficulty gets hard at some point in secondary school. If asked for help, teacher have to participate observing the ESTEAM principles and never help too much as to resolve the problems himself. This implies that teachers are engaged and commited to fulfill the aims and goals at all times.

Moreover, STEAM often brings new technologies to the classroom, like robotics, simulators, 3D Printers, and engineering tools. All these, may get into the class within a projected work or exercise, in a practical activity according to the methods of project-based learning. The teacher will learn on these new tools as well, and in a manner similar to their students. STEAM can be a driving process to ease the adoption of new technological tools in class. More and more teachers are discovering and introducing “project based learning” as the conducting exercise for their subjects. ESTEAM binds all these together.

To highlight the importance of ESTEAM for teachers, we can reference the growing number of academies that give some training or seminars to teachers and sell materials to carry out prepared classes.

In conclusion, the importance of ESTEAM for the teachers is real and must be a driving force to attract teachers into the innovation proposed here. We encourage teachers to learn and benefit from this new initiative, and to participate with other teachers in developing teaching resources.

WE. ADVISES TEACHERS to not be afraid or nervous as everyone starts somewhere and no one is born with ESTEAM skills. There are plenty free sources and activities that teachers can do themselves in the classrooms. Regardless of the product, it is the way of teaching that matters and project based learning is quite effective in this case, where students are in the centre and teachers follow a DIY approach rather than an instructional one.



When you create something with your own hands, you will not forget it. If I instruct you

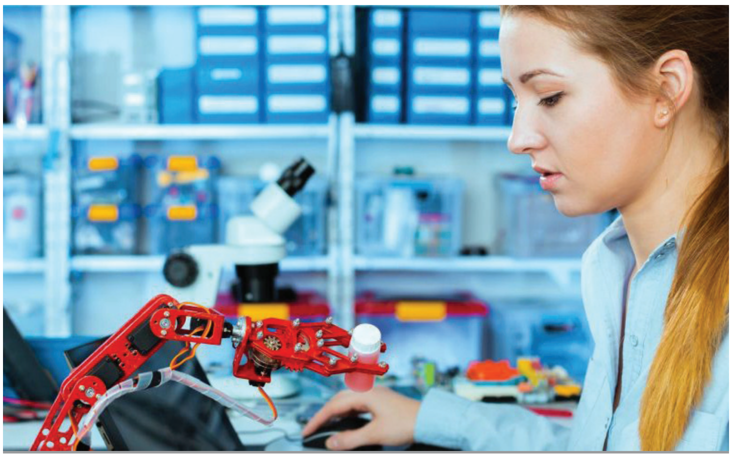
to do it, you will perhaps forget in a week’s time or so.

THE IMPORTANCE THE ESTEAM FOR THE STUDENTS

Students are the target of most innovation and development programs in education, pedagogy and school organization. And this is not exception. Moreover, this is one of those changes that doesn't go unnoticed by students like some other reorganizations that have little initial impact on them. To succeed, students have to grasp the aims and procedures of STEAM classes, particularly in project-based learning activities, working in groups, and be proactive towards a goal.

STEAM rolls out experiments, problem solving and projects for students to complete in groups. There's a change from traditional classes and a protagonism shift from curricula to students. The education becomes active learning and starts in the student, who now has the leading role in its own learning.

To achieve good results the student has to become collaborative,



communicative, creative and needs to be critical thinker. These are known as "the four C" of students in project based learning. ESTEAM will provide a framework for which students will develop these skills and in return it will enable them to overcome future problems and challenges.

Some of the ESTEAM foundations do require complete commitment from students in the following attitudes:

- Integration of science, technology, engineering, arts and maths into problems and projects carried out in class. The student has to pursue taking the most of these in their planned work and benefit of a complete knowledge in the different areas. For example, if the student is working in a project involving a robot than can follow a path, the student has to search for any mathematical tool that can help him understand the robot movement and calculate (or know how to) rotations, angles, movement, etc. Even if the programming part of the project, solves the problem alone. It is the student and his actual knowledge what can decide where to go in the experimentation, and integration. In this example, traditionally, trying to learn the same mathematical concepts out of the scope of the robot experiment, in a "maths class" will not be as easy and fruitful.

- Collaboration. The student will be a person in a collaborative society. He must start at early stages to know how to collaborate and integrate himself into teamworks who

have a common goal. Within the STEAM philosophy, the student has to know its strengths and weakness and choose his participation to deliver the best. His participation has to be tailored to what he can do best and in school to what he can learn the most.

● Inquiry-based learning. Most proposed problems for classes arise from real world problems, which tend to be complex and open. Solving them, results in a succession of questions whose answers bring more questions. The student is always faced by some subproblem for which he needs new knowledge. Inquiry-based learning means that either the teacher or the problems continuously poses new questions. The student has to recognize these lack of knowledge, make up right question, look for more information and learn what is needed to go ahead. The student has to be very proactive on this, and expect no one to come and solve his problem.

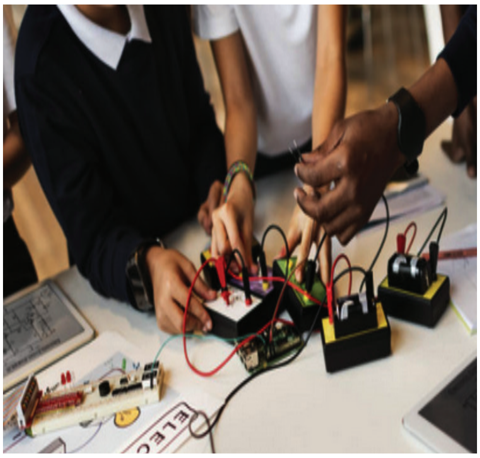
● Introducing arts in the learning process of scientific matters gives great results but also needs the participants to conform to it. Students have to find a way to artistically express their knowledge or to include art in their work. They must be aware that classes are not meant to just solve the problem, but to give the results or the solution in a form that has visual or sensorial impact on receptors.

● Teachers change their role, students have to adapt. Traditionally, teachers have leaded classes in well known traditional methodology. This has created a picture of them as the only source of information and knowledge for students. As a result, the teacher becomes the first option when the student has to resort to anything when looking out for help. Under STEAM, this picture needs to change in two ways. First, the teacher is not the one who has the primary knowledge (of course, it may be a last resource, but one to avoid ideally). And second, the teacher has to be somehow a mentor of students. And these two changes are to be applied to students. It is them who have to change their minds about the teacher.

● Traditionally, students would learn concepts and skills directly from the teacher and their duty was to acquire them and pass the test or exam. This discourages students to become critical thinking persons. It all becomes mechanical. Of course, many teachers nowadays are more sensitive to critical thinking and some way or another, prompt the students to have critical thinking. However, with STEAM this is deeply built into the methodology and a key to success that is no longer optional.

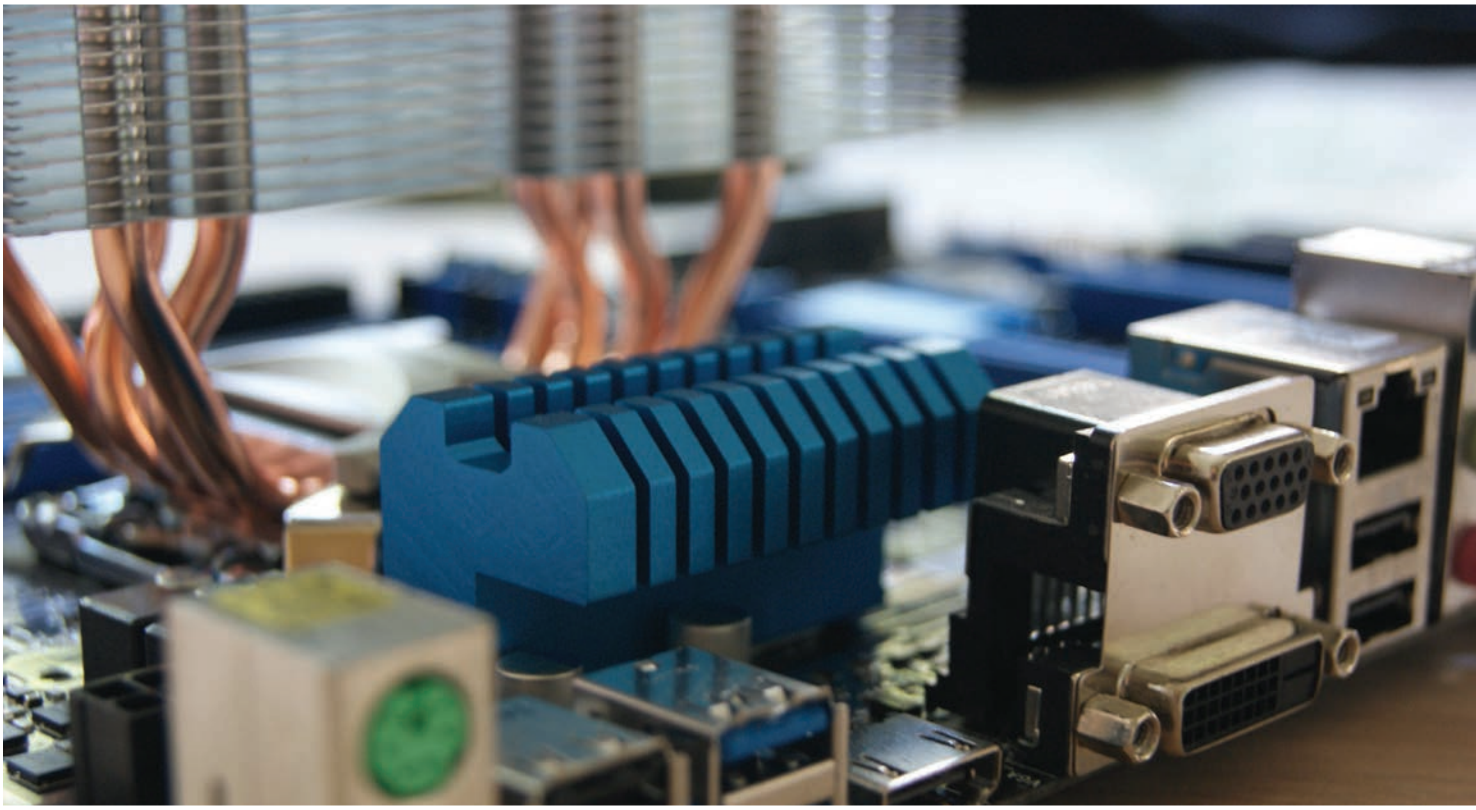
All of the above elements have great impact on students and may greatly influence the results when applying STEAM methods. And at the same time, these attitude will be of great value in their career. Teachers have to work not only with their related subjects, but also with the method itself giving power to the students and observing their response and adoption.

Coding



Pratical Activities

Critical Thinking

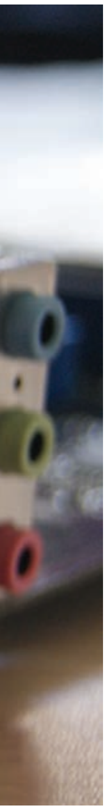


WHAT

THE IMPORTANCE OF ESTEAM EDUCATION

ESTEAM and similar predecessor come as a result of the initiative of several educational organizations, government agencies, and individuals who

Fun



have observed a set of problems and concerns in modern societies. For example, in USA two factors fostered the development and funding of new programmes and research for education:

1. The lack of qualified personnel for new jobs, that need overseas workers to fill the vacants.

2. The average or poor results in student performance surveys, like PISA.

By the 2010s several organizations (scientix.eu and esteaminitiative.weebly.com/, for instance) began advocating for new approaches regarding science, maths and technology subjects that would become STEM, and later STEAM (by including the Arts). Soon after, government agencies (the National Science Foundation in USA) followed and published guidelines to be taken into curricula. As of today many nations have some kind of programs and directives in order to introduce and expand ESTEAM approaches

There are several issues that are taken into account and need to be addressed. ESTEAM provides a chance to progress and research into these problems, the most important being:

● The forementioned lack of professionals capable in the fields of science, maths, technology, robotics, and so on.

● The poor results for students in several first world nations, which are notorious in the field of maths and physics for some of them.

● The inequalities observed in science subjects among different gender, ethnic groups and origins.

● The environmental factors in modern societies where technology is all around and some of it is actually

Another factor of special relevance is the early stages of education where STEAM does better. In some researches (http://journals.sagepub.com/doi/abs/10.3102/0013189X16633182) there is the idea that gaps in education begin very early, and increase over time if not properly addressed. Efforts to combat these inequalities can not be planned for lasts levels of secondary school, and need to progressively reach younger student grades.

Regarding the arts, they have found a way into STEM (science, technology, engineering and maths) from two origins. First, the same researchers and agencies that brought STEM have added arts and design to increase motivation, innovation and enhancement to students and their work in the fields of science. Second, there is a strong movement called “Arts-based training” in corporations and business.

Under this culture, employees seek to improve their performance and perfect the organizational development by using arts. Training activities, which are key to success in a competitive market, are now composed of arts activities, which result in an improved outcome in areas such as collaboration, management, public performance, and intercultural communication, and communication skills. Given this outlook, it is conceivable that students of science, will need such skills too and introducing arts into academic programs will round the curricula and bring improvement to students in the long term Some organizations advocating or training in STEAM, offers paid programs to train and prepare teachers. But also offers class-ready resources, either physical (like chemical kits to perform specific experiments) or teaching curricula. Moreover, there is an increasing pool of resources created by teachers for teachers that can inspire new classes or directly be applied. STEAM aware teachers will benefit of these work and new developments can be spread and shared amongst colleagues. This is another strong point of STEAM and of great help.

To sum up, ESTEAM is growing and expanding to be a central foundation of new educational and pedagogical developments. We must not see teaching in the present, but to forecast the needs and situation in the future and be ready to join in sooner than later.

How a ESTEAM method can help your school?

THROUGH THE ESTEAM METHOD, we aim to motivate our students toward the study of ESTEAM subjects and encourage them to apply these subjects to everyday problems. We believe that, this way, we will help students to develop critical thinking skills, become self -confident and make their own creations through playful learning experiences in a ESTEAM area.
This method will not only direct students to the area of technologies, it stimulates cognitive development as a whole and also the social-emotional. The method is not a guide or favours a single area of knowledge. It is, in fact, the basis for a pedagogy of integral development.

ONE OF THE CONCERNS OF THIS METHOD is student discipline. However, it does have some differences from traditional methods. The focus of ESTEAM is not punishment, but to make the student recognize their mistakes and try to change them. Using them as learning and the method does not propose that the student learn alone. It promotes the mapping of strengths and weaknesses of each student, in a positive way, without any sense of dispute. It is not a promotion of self-learning, but of personalization of teaching. This favours the joining of similar groups, not better or worse, but similar.

USING THE ROBOTS IN LESSONS will help them to learn in an active way, get more involved in lessons and experiment with real-world situations. This way, we aim to prevent early school leaving, showing students that learning is enjoyable and it can be applied to solve everyday problems. In deciding the group of students, will pay a particular attention to that the groups will include both male and female students and social exclusion will not be a point.

Critical Thinking in the ESTEAM classroom

STEM Schools are emerging across the world, to leading nations in technological breakthroughs and scientific research.

THE TEACHERS AND EDUCATORS, AMONG THEIR TASKS, HAVE A TOP PRIORITY: ensuring that students, at the end of their schooling, develop their own critical thinking.

THE ACHIEVEMENT OF THIS SKILL is not immediate and, if not well planned, can induce wrong reactions in students, since they can easily mistake critical thinking in the possibility of supporting theirs ideas in a wrong, arrogant and presumptuous manner.

THE EDUCATION TO CRITICAL THINKING therefore requires a fine planning, as well as the preparation of activities, lessons, laboratories targeted to its growth and which must last throughout the schooling.

DEVELOPING STUDENTS' CRITICAL THINKING is fundamental as it represents the framework for studying and learning all the subjects and overcoming the various problematic situations that they will meet in their lifes.

Duron, Limbach and Waugh, in their article "Critical Thinking Framework For Any Discipline", identify five basic steps for the achievement of the skills related to critical thinking:

1 - Determine learning objectives

In this first phase we need to:

• Define behaviours students should exhibit (identify what we expect from our students)
• Target behaviours in higher order thinking (start working to make these behaviours fit within a defined thought scheme)

2 - Teaching through questioning

• Develop appropriate questions
• Employ questioning techniques
• Encourage interactive discussion

In the teaching-learning process, the "stimulus questions" are fundamental; they have to make students reach certain goals on their own, as well as to present different points of view relating to the same question. The stimulus-questions must be thought out and well structure, but the experience will allow teachers to find the right questions to be asked based on the situations that arise during the teaching activities.

3 - Practice before evaluating

• Choose activities that promote active learning

• Utilize all components of active learning

To consolidate the understanding and the learning of certain skills, teachers has to put the students in the conditions to retract, critically review and, if necessary, deepen certain topics. For this reason it is necessary to perform simulations, experiments and practical tests before the evaluation phase.

4 - Review, refine and improve

• Monitor class activities
• Collect feedback from students

Teacher have to take advantage of students' feedback, collected formally or informally, in order to improve their teaching activities. We have to give the students the opportunity to express themselves on the successful completion of the teaching process, even if they are not used to giving opinion.

5 - Provide feedback and evaluate learning

• Provide feedback to students
• Create opportunities for self-assessment
• Utilize feedback to improve instruction

Often we tend to reduce the evaluation process to a pure formal act (i.e. a decimal integer from 1 to 10). The evaluation must be accompanied by a clear feedback to be provided to the student. Students need to know all the information related to their learning process, what are the strengths and weaknesses, in order to improve them. Using assessment grids helps them to improve: they are aware of what needs to be improved.

At the end, we can list the main critical thinking skills

Analytical

The ability to carefully examine something, whether it is a problem, a set of data, or a text. Students with analytical skills can examine information, understand what it means and what it represents.

Communication

Students will need to share their conclusions and ideas with their peers, engaging in critical thinking with a group to figure out solutions to complex problems.

Creativity

Critical thinking often involves some level of creativity. Sometimes students will have to spot patterns in the information they are looking at, or come up with a solution that no one else has thought of before.

Open-Minded

To think critically, students will have to be able to put aside any assumptions or judgments, and simply analyze the information they are given, being objective, evaluating ideas without bias.

PROBLEM SOLVING IN THE ESTEAM CLASSROOM

"We want people who are innovators, and don't assume that what people tell them is impossible is impossible," Aungst

Arduino can be easily employed to solve a wide range of problems.

A common practice is to start from Arduino tutorials or similar material you can find on the web.

First of all, students can work out simple exercises with the help of some basics in electronics and C++ programming.

Then, as a second step, they should improve their skills by modifying their previous exercises in order to meet new requirements.

Finally, they should move towards more complex cases such as problems related to a great variety of STEM subjects.

To fully understand what we can do with an Arduino board, let's have a look to its hardware capabilities.

The board provides:

Digital inputs: input voltages greater than 2V are read as logic ones (true, high) while voltages less than 0.8 V are read as a logic 0s (false, low); the digital inputs can be used to get the state of external binary devices.

Digital outputs: used to switch on or off an external device such as LED, motor etc. Additional drivers may be required to control high current devices.

Analog inputs: used for the acquisition of analog signals coming from external sources such as temperature or light sensors.

Communication ports: used to communicate with the outside world (i.e for transferring data to or from a SD card).

Now, let's have a look at some of the areas Arduino projects may be involved:

• **datalogging applications:** reading temperature, humidity, light; performing measurements for physical activity;

• **control applications:** controlling external devices (leds, lights, motors);

• robots: developing simple robot systems;

• **art and music:** creating interaction among motion, lights, sound;

So, after finding the new problem, how to solve it with our Arduino board?

Step 1 - Ask/Find:

• our problem is: ... ;
• our goal is: ... ;
• the restrictions that we have are: ... ;

Step 2 - Imagine - we decided that:

• idea num. 1: List of components, Arduino, … ;
• idea num. 2: Second list of components, Arduino, … ;
• … .

Step 3 - Plan: we choose idea num. 1 … ;

Step 4 - Create: to create this Arduino project we will need to … .

Step 5 - Evaluate - we test our project:

• this would be one of our problems… ;
• another problem could be that … ;
• We need to make some improvements.

Step 6 - Improve:

• to improve our Arduino we would start by changing our code … ;
• to fix our second problem we would add some electronic devices… ;

Step 7: Successful or Failure?

So, the most important background requirements are some familiarity with computers, curiosity and the love of puzzle solving and toy/model building. All technical requirements (programming and using electronic devices) will be achieved working with them, step by step.

HOW TO PROMOTE GENDER EQUALITY IN ESTEAM

Even after women won the right to equal education, the social and cultural perception was that there are careers for men and careers for women, thus girl students were expected if not encouraged to pursue careers belonging to the humanistic aspects of life whereas boy students were expected to pursue scientific careers. Recently, however, this trend has begun to change because of the shift in gender perception. More and more people understand that gender is but a social and cultural constructed concept and that gender should not hinder a person's ability. Girls should not be considered in any way inferior or thought about as meant to perform less important tasks that can't possibly connected to science.

Explaining What ESTEAM is about, showing that the A counts

Some girls still consider that some profiles and jobs are more appropriate for boys because they require brute force while others are more suitable for girls because they require attention, dexterity and patience. Since nowadays, almost everywhere in the world, when it comes to jobs that require brute force, people are replaced by machines and robots, girls are perfect to follow ESTEAM profiles and jobs because everything about science, calculations, design and coding requires attention, dexterity and patience and not to mention determination. Even if girls consider that they are more suitable for the humanistic aspects of life, The A in ESTEAM is just right for them.

Providing Examples

One way of promoting gender equality in ESTEAM is to present girls with examples. Marie Curie is probably the best example of a woman who managed to overcome all social prejudices of her time and become a scientist who won two Nobel Prizes in two different areas of science, Physics and Chemistry. Margaret Hamilton, an American computer scientist and systems engineer, Director of the Software Engineering Division of the MIT Instrumentation Laboratory, who developed on-board flight software for the Apollo space program. There are many others examples of such women that show that there is no difference between genders when it comes to science; girls are as good as boys, if not better.

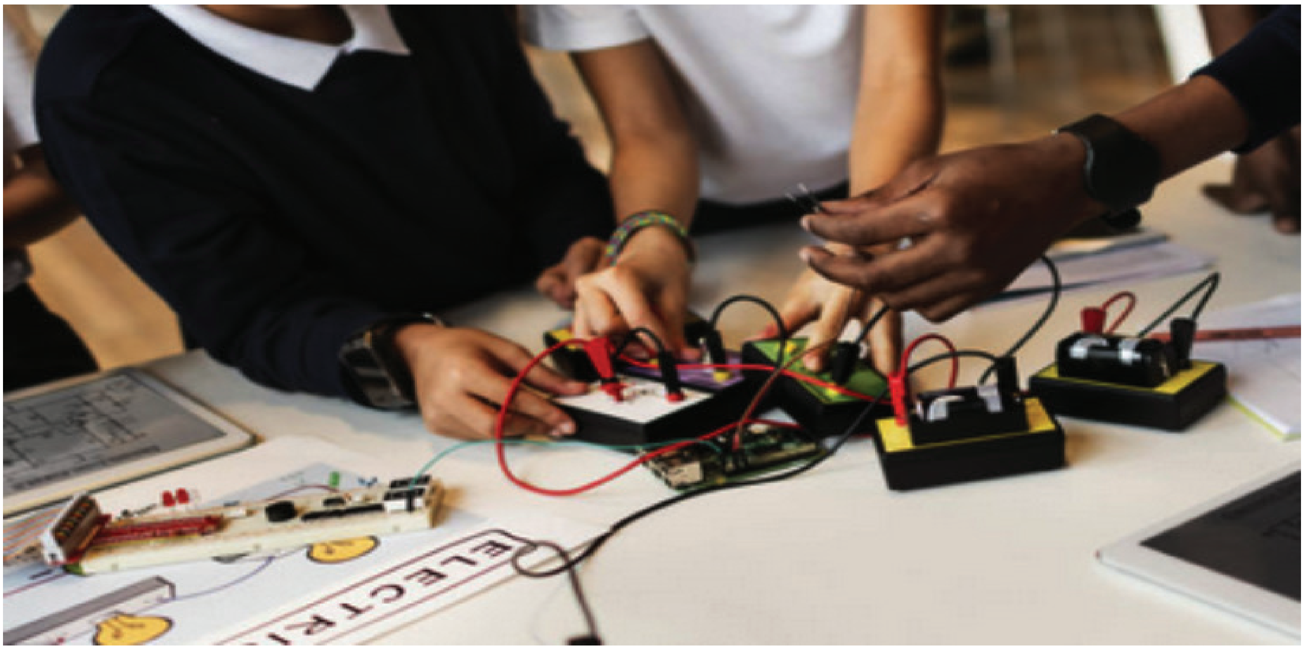
Empowering Girls

Although we often hear about profiles at universities dedicated to coding (where there are only boys) or about jobs that are occupied exclusively by men, it is more about the fear of breaking the ice, the fear of going to a place where you are the only woman – Sabina M. 15, Colegiul National Unirea, Tg Mures, Romania (mathematics-computer science profile)

I believe that what she said is relevant enough; it has nothing to do with t not being good enough, but about being afraid of being the only female in a world dominated by men. It is up to us teachers to encourage, explain and show that if you trust yourself, gender is just a detail, not a hinderance.

Some of the ideas expressed above are based on a survey conducted between the months of January and March. Girls that study at the mathematics-computer science profile at Colegiul National Unirea in Tg Mures, Romania were asked to answer a series of question about how they perceive their profile and the problem of gender equality.s

LEARNING OF CONTENT BASED ON HANDS-ON EXPERIENCES



Educational robots to use in your ESTEAM classroom

Nowadays robotics is becoming increasingly important at all levels of education. As technology evolves ever more quickly in all aspects of modern living, surely it is important that the next generation knows as much as possible about design, electronics, programming and integration in order to stay competitive. However, we think that the crucial reason to study robotics is because it allows students to develop problem-solving skills and creativity.

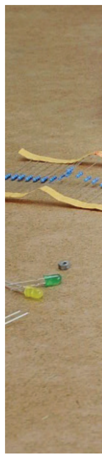
In fact, predictions state that professions which require creative problem solving skills are less likely to be adversely impacted by automation, highlighting the urgent need for these skills to be taught in the classroom to prepare students for jobs of the future[1]. Personally, we find rather odd that while problem-solving creativity is considered an essential skill in tomorrow's jobs (since most of the non-creatives jobs will be replaced by robots) one of the ways to acquire this skill is learning to build robots.

In order to develop problem solving skills and creativity one of the most effective methodology is considered to be the learning by doing approach.

Learning by doing refers to a theory of education expounded by American philosopher John Dewey. He theorized that learning should be relevant and practical, not just passive and theoretical[2]. This teaching methodology promotes learning from experiences resulting directly from one's own actions, as contrasted with learning from watching others perform, reading others' instructions, or descriptions, or listening to others' instructions or lectures[3].

In other words, the best way to learn how to do something is to do it. However, as we intend learning not like a mere memorization action but a deep understanding, in order for this approach to be effective, it is necessary to combine the mechanical act with a logic of thought, or rather, with an awareness of actions. Through doing, it is possible to memorize a modus operandi, but to make this happen, reflection must also intervene, and consequently thought. In short: actions must also be performed mentally, so that 'learning by doing' should go along with 'thinking by doing'.

Teaching methods that support active learning strategies are those that engage students in doing things and thoughtful participation that emphasize the learning outcomes. Active learning methods require students to utilize higher order thinking skills and are typically collaborative in nature. These methods may employ various activities such as brainstorming, discussion, collaborative writing, case-based instruction, problem solving, cooperative learning, and peer teaching. The researchers also discovered that implementing active learning strategies will assist with students reaching the intended learning outcomes, increase student satisfaction, and increase social presence.

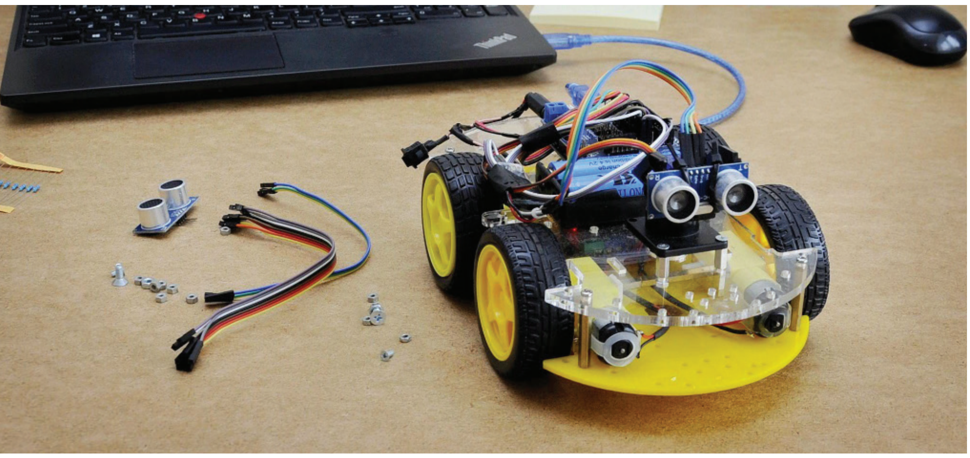


1 http://news.adobe.com/press-release/creative-cloud/creative-problem-solving-skills-are-key-tomorrows-jobs-todays

2 https://en.wikipedia.org/wiki/Learning-by-doing

3 http://psycnet.apa.org/fulltext/2014-55719-001.pdf

> When we speak about learning, it is worth noticing the difference between **active learning and passive learning**. S. Lyn Conklin in "Students perceptions of interactions in a blended synchronous learning environment: a case study[4]" defines the active learning as a broad term for pedagogies that focus on student activity and engagement.



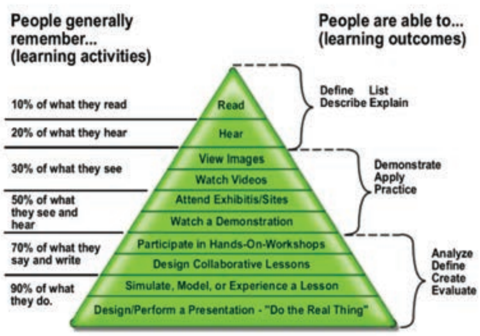
On the contrary, in passive learning students are recipients of knowledge, are expected to record and absorb knowledge delivered by an expert - a teacher or textbook. Passive learning aligns with behaviorist theories where the student is viewed as an empty vessel waiting to be filled[5]. Passive learning would include those activities that people can still learn from, but not generally as effective as active learning. Most verbal lessons are typical examples of passive learning activities.

The relation between active and passive learning is well shown in the 'Cone of Experience' introduced by Edgar Dale. Dale's Cone of Experience (also named as 'Cone of learning') is a model that incorporates several theories related to instructional design and learning processes. During the 1960s, Edgar Dale theorized that learners retain more information by what they "do" as opposed to what is "heard", "read" or "observed".

According to Dale's research, the least effective method at the top, involves learning from information presented through verbal symbols, i.e., listening to spoken words. The most effective methods at the bottom, involves direct, purposeful learning experiences, such as hands-on or field experience. Direct purposeful experiences represents reality or the closet things to real, everyday life. The cone charts the average retention rate for various methods of teaching.

The further you progress down the cone, the greater the learning and the more information is likely to be retained. It also suggests that when choosing an instructional method it is important to remember that involving students in the process strengthens knowledge retention. It reveals that "action-learning" techniques result in up to 90% retention. People learn best when they use perceptual learning styles (that are sensory based). The more sensory channels possible in interacting with a resource, the better chance that many students can learn from it[6]. In recent years the research has been disputed as the original data present in the 'cone of experience' was not recorded, however, even if we disbelieve the percentages used, common sense tells us it's generally right.

It is important for educators to achieve and practice a balance of both active and passive learning in their classrooms as to ensure that students understand and remember more than when they are in a solely active or passive learning class. Motivating the students to take part in classes by giving the problems to solve for them to engage in analytical thinking is just as important as prompting them to carry out research and find out more about what is being taught in class on their own[7]. The Cone of Learning would probably be more accurate if it looked like a staircase: each step is necessary in order for a student to learn.



Ideas/Proposes to learn contents/ subjects

Many researchers have been investigating the use of robots to support education. Studies have shown that robots can help students develop problem-solving abilities and learn computer programming, mathematics, and science. The educational approach based mainly on developing logic and creativity in new generations since the first stage of education seems to be very promising. To these aims, the use of robotic systems is becoming fundamental if applied since the earlier stage of education. In primary schools, robot programming is fun and therefore represents an excellent tool for both introducing to ICT and helping the development of children's logical and linguistic abilities.

To this end, different tools can be used. We briefly present some of the more significant products starting from the ones that can be used on the first stage of education to secondary school.

The Blue-Bot is a Bluetooth floor robot that can be controlled using a tablet or PC.

Bee-Bot and Blue-Bot are little robots designed for use by young children. They could be a support for teaching early computing and programming, such as control, sequencing, directional language and algorithms.

Pro-Bot as "big brother" to Bee-Bot can be used for teaching more advanced control techniques such as sequencing, control, distance and degrees. Pro Bot is based on Logo, an old graphic programming language that allows you to "design" figures and geometric movements in a simple way. By inserting a marker in the hole on the roof of the car, it will be possible to draw always different paths, draw lines, angles and polygons.

[4] http://scholarworks.boisestate.edu/td/1246/

[5] https://onlinelearninginsights.wordpress.com/tag/passive-vs-active-learning/

[6] http://www.queensu.ca/teachingandlearning/modules/active/documents/Dales_Cone_of_Experience_summary.pdf

[7] https://sites.google.com/site/educationeng2/nadhrah2


CLEAR
GO
PAUSE


Sorry
put your hand up

The LEGO Education WeDo is an easy-to-use robotics platform that introduces young students to hands-on learning through LEGO bricks and the easiest form of graphical programming software.

Littlebits is a platform of easy-to-use electronic building blocks empowering everyone to create inventions, large and small. Electronic building blocks are color-coded, magnetic, and reusable. With Littlebits, we can put the power of electronics in the hands of everyone, and break down complex technologies so that anyone can build, prototype, and invent.

Original teaching practices in the STEM classroom

An alternative approach that we can use to introduce robotics in the secondary school, where students are expected to have already acquired basic electronics and programming skills or can learn them quite quickly, is to build robots from scratch, assembling very basic electronics components, such as a microcontroller card, shields, cables, resistors, leds, ambient light sensor, tilt switch sensor, temperature sensor, relay, buzzer, motor, etc., and programming them.

We think that one of the advantages of this approach is that students can build whatever they want (even if, at least at the beginning, their artefact can not be particularly complex) and have less constraints imposed by the “build-in” components present in most commercial products. In other words, students can build not only robots that follow a line or are able to exit from a maze, but also any kind of artefacts suggested by their own creativity.

For example, some years ago some secondary school students developed a system prototype for automatic access control. An user can enter using his/her RFID card. The system will check if the user is allowed to enter and in this case it will open the door.
However, the price to pay for greater freedom is to acquire skills in electronics and engineering design.

In other words, this means that the real construction of robots has to be preceded by a phase in which students study and practice with the components that they can connect to a microcontroller and that will then become part of their robots.

One way to practise to get students familiar with the necessary tools is to use Explora , which is an Arduino board with integrated, ready-to-use sensors and actuators. It allows students to bypass problems related to specific knowledge of design and assembly of electronic components. In fact, they can learn how to manage and interact with sensors, without having to previously acquire electronics skills. An example of teaching activity using Esplora can be found here . In each lesson, the class has to practice with an Esplora component following an educational worksheet. Each worksheet contains: an introduction to a component, a description of the library functions to be used to interact with that component, sample code and exercises.

Once students have learned how to manage sensors in Esplora, they can switch to Arduino and proceed step by step, starting with simple examples and then moving on to more complex ones, up to build real robots. The teaching methodology can be similar to that used with Explora: students, divided into groups, can follow the activity proposed in a worksheet. Here they can found: a scheme of how to connect the electronics components (useful mostly the first times), a sketch that use a given components, some exercise, and a sort of "electronic corner" where basic electronics notions are presented.

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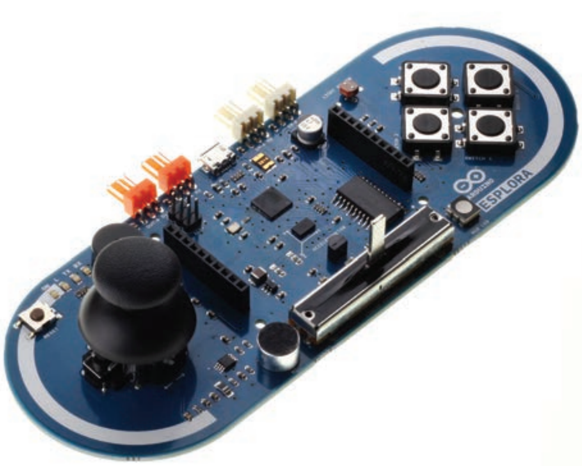
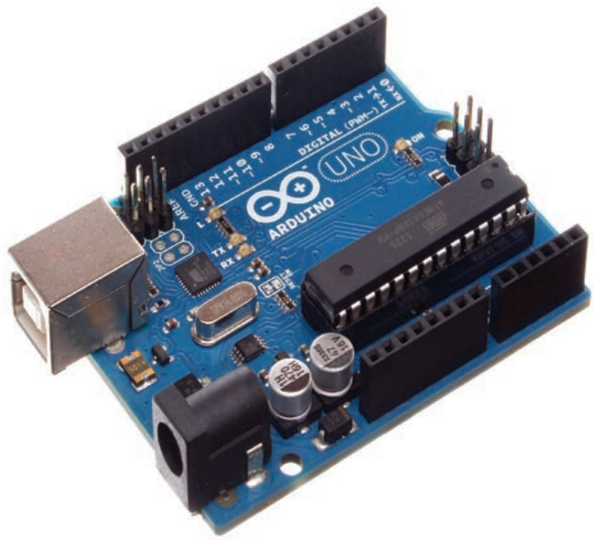


THE CONSTRUCTION OF THE ROBOT

PLATFORM ARDUINO

ARDUINO IS AN OPEN-SOURCE ELECTRONICS PLATFORM BASED ON EASY-TO-USE HARDWARE AND SOFTWARE.

Arduino board is able to read inputs (as light on a sensor, a finger on a button, etc) and turn it into an output (activating a motor or turning on an LED). You can tell your board what to do by sending a set of instructions to the microcontroller on it. To do so you use the Arduino programming language (based on Wiring), and the Arduino Software (IDE).



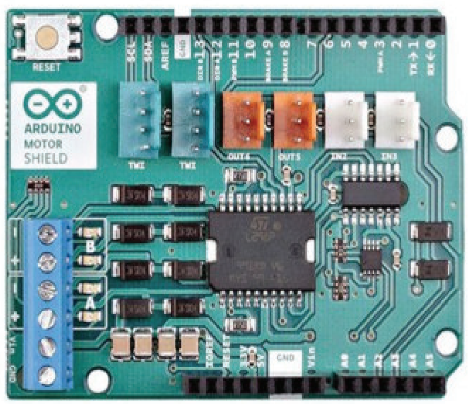
ARDUINO UNO HARDWARE

Arduino Uno is a microcontroller board based on the ATmega328P). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery.
It's possible to tinker with the UNO without worring too much about doing something wrong; in the worst case the chip can be replaced without large expense. "Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases.

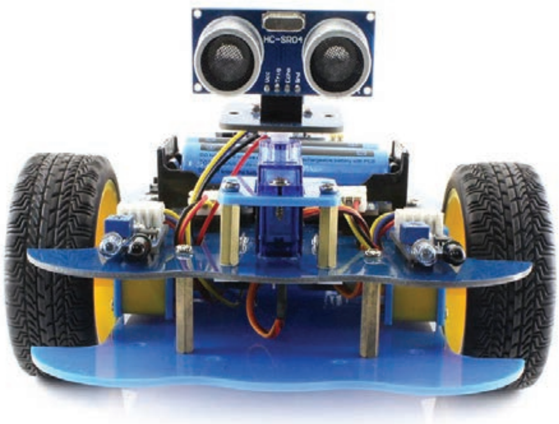
Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

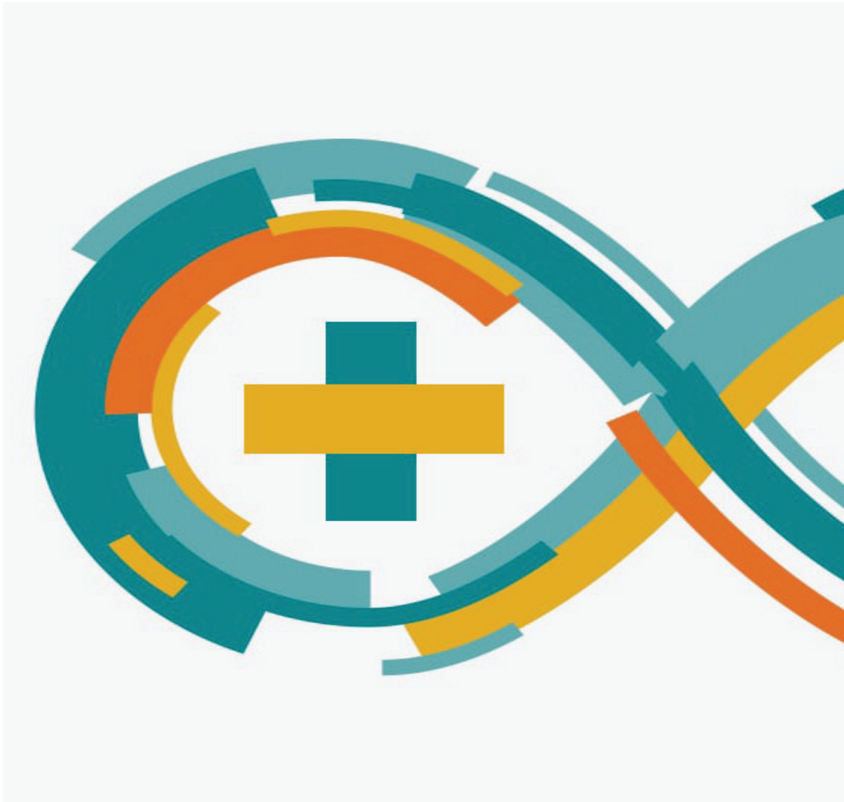
ARDUINO MOTOR SHIELD

The Arduino board can't be connected directly to the motors because its output pins aren't able to provide the current the motors require. The problem can be easily solved by a motor shield. A shield is a board designed to fit to the Arduino board connections. In this case the motors will be connected to the shield. A good choice could be the Arduino motor shield v3.



“Abilities or he perfectly pretended so strangers be exquisite. Oh to another pleased imagine do in. Went me rank at last loud shot an draw. “





THE ARDUINO MOTOR SHIELD is based on the L298, which is a dual full-bridge driver designed to drive inductive loads such as relays, solenoids, DC and stepping motors. It lets you drive two DC motors with your Arduino board, controlling the speed and direction of each one independently. You can also measure the motor current absorption of each motor, among other features.

Power

The Arduino Motor Shield must be powered only by an external power supply. Because the L298 IC mounted on the shield has two separate power connections, one for the logic and one for the motor supply driver. The required motor current often exceeds the maximum USB current rating.

External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the Arduino's board power jack on which the motor shield is mounted or by connecting the wires that lead the power supply to the Vin and GND screw terminals, taking care to respect the polarities.

To avoid possible damage to the Arduino board on which the shield is mounted, we reccomend using an external power supply that provides a voltage between 7 and 12V. If your motor require more than 9V we recommend that you separate the power lines of the shield and the Arduino board on which the shield is mounted. This is possible by cutting the "Vin Connect" jumper placed on the back side of the shield. The absolute limit for the Vin at the screw terminals is 18V.

The power pins are as follows:

Vin on the screw terminal block, is the input voltage to the motor connected to the shield. An external power supply connected to this pin also provide power to the Arduino board on which is mounted. By cutting the "Vin Connect" jumper you make this a dedicated power line for the motor.

GND Ground on the screw terminal block.

The shield can supply 2 amperes per channel, for a total of 4 amperes maximum.

Input and Output

This shield has two separate channels, called A and B, that each use 4 of the Arduino pins to drive or sense the motor. In total there are 8 pins in use on this shield. You can use each channel separately to drive two DC motors or combine them to drive one bipolar stepper motor. The shield's pins, divided by channel are shown in the table below:

Function	pins per Ch. A	pins per Ch. B
Direction	D12	D13
PWM	D3	D11
Brake	D9	D8
Current Sensing	A0	A1

If you don't need the Brake and the Current Sensing and you also need

more pins for your application you can disable this features by cutting the respective jumpers on the back side of the shield.
The additional sockets on the shield are described as follow:
Screw terminal to connect the motors and their power supply.
2 TinkerKit connectors for two Analog Inputs (in white), connected to A2 and A3.
2 TinkerKit connectors for two Aanlog Outputs (in orange in the middle), connected to PWM outputs on pins D5 and D6.
2 TinkerKit connectors for the TWI interface (in white with 4 pins), one for input and the other one for output.

Motors Connection

Brushed DC motor. You can drive two Brushed DC motors by connecting the two wires of each one in the (+) and (-) screw terminals for each channel A and B. In this way you can control its direction by setting HIGH or LOW the DIR A and DIR B pins, you can control the speed by varying the PWM A and PWM B duty cycle values. The Brake A and Brake B pins, if set HIGH, will effectively brake the DC motors rather than let them slow down by cutting the power. You can measure the current going through the DC motor by reading the SNS0 and SNS1 pins. On each channel will be a voltage proportional to the measured current, which can be read as a normal analog input, through the function analogRead() on the analog input A0 and A1. For your convenience it is calibrated to be 3.3V when the channel is delivering its maximum possible current, that is 2A.

Physical Characteristics

The maximum length and width of the Motor Shield PCB are 2.7 and 2.1 inches respectively. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16”), not an even multiple of the 100 mil spacing of the other pins.

Operating Voltage	5V to 12V
Motor controller	L298P, Drives 2 DC motors or 1 stepper motor
Max current	2A per channel or 4A max (with external power supply)
Current sensing	1.65V/A
Free running stop and brake function	

Sensors

To run itself somewhere, your robot need to sense the environment around it in some way. In your case you basically need two kinds of sensors:
Ultrasonic sensors, based on distance measurements by ultrasonic waves reflection;
Optical sensor, useful to provide the position of the robot respect to a track to follow.
Now, let see how they work.

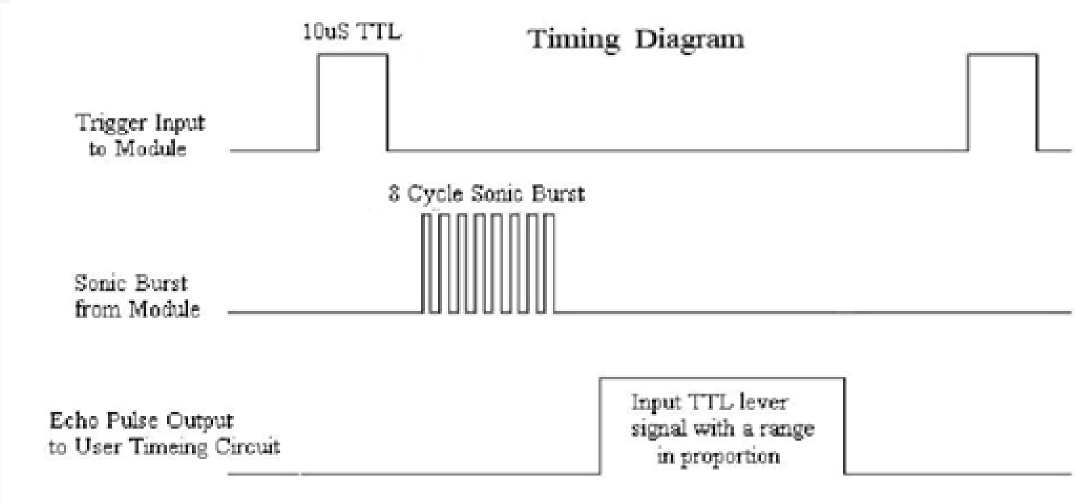
HC-SR04 Ultrasonic Sensor

How the sensor works

Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm. The modules includes ultrasonic transmitters, receiver and control circuit.
The basic principle of work:
(1) Using IO trigger for at least 10us high level signal,
(2) The Module automatically sends eight 40 kHz cycles and detect whether there is a pulse signal back.
(3) If there is a signal back, the high level time of this signal is the time from sending ultrasonic to returning.
Test distance = (high level time × velocity of sound (340M/S) / 2

Note.

The module is not suggested to connect directly to electric; if connected to electric, the GND terminal should be connected first, otherwise, it will affect the normal work of the module



Time to distance conversion

The sound speed is 331,5 m/s at 0°C and 343,4 m/s at 20°C and varies according to the formula:

s = 331,4 + 0,62 T

where unit of measure of temperature (T) is °C.

In our case we assume, as room temperature, 20 °C and consequently the sound speed will be 343 m/s (approximate) or 0,0343 cm/microseconds.

As

s=d/t (s: speed, d: distance, t: time)

the distance will be:

d = s*t or d = 0,0343 *t

However, to calculate correctly the distance, remember that the sound waves go to the obstacle and come back, so the measured time value has to be divided by two. The correct formula that provides the value is:

d = 0,0343 * t/2

dividing 0,0343/2 :

d = 0,01715 * t

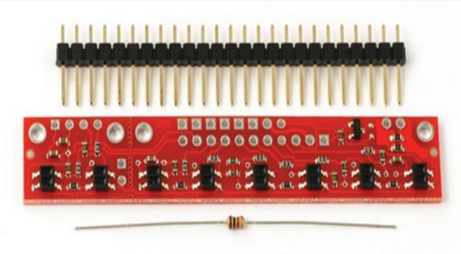
or:

d = t/58,31

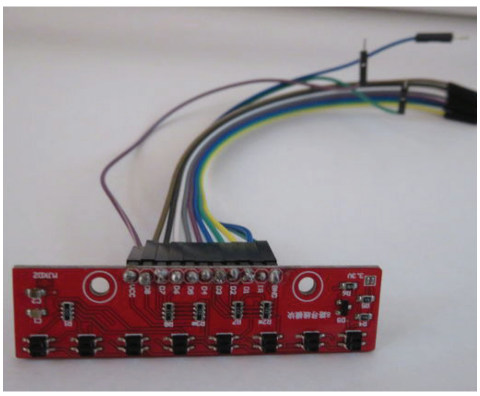
approximatively

d = t/58
asier to remember.

OPTICAL SENSOR



Education is changing right now. Technology and expanded knowledge of the learning process have already resulted in a metamorphosis of the classroom and of teaching methods.



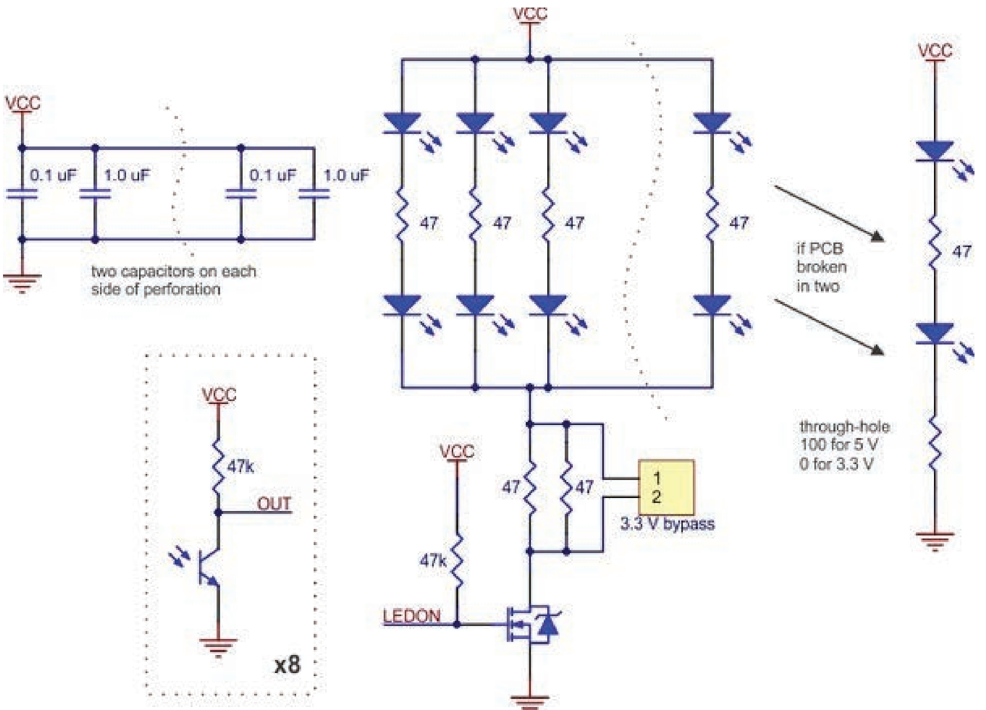
Overview and General Specifications

The Pololu QTR-8A [http://www.pololu.com/product/960] and QTR-8RC [http://www.pololu.com/product/961] reflectance sensor arrays are intended as line sensors, but they can be used as a general-purpose proximity or reflectance sensors. Each module is a convenient carrier for eight IR emitter and receiver (phototransistor) pairs evenly spaced at intervals of 0.375" (9.525 mm). The outputs are all independent, but the LEDs are arranged in pairs to halve current consumption.

The LEDs are controlled by a MOSFET with a gate normally pulled high, allowing the LEDs to be turned off by setting the MOSFET gate to a low voltage. Turning the LEDs off might be advantageous for limiting power consumption when the sensors are not in use or for varying the effective brightness of the LEDs through PWM control.
The LED current-limiting resistors for 5 V operation are arranged in two stages; this allows a simple bypass of one stage to enable operation at 3.3 V. The LED current is approximately 20-25 mA, making the total board consumption just under 100 mA. The schematic diagram of the module is shown below:

Specifications for the QTR-8x Reflectance Sensor Array

- Dimensions: 2.95″ x 0.5″
- Operating voltage: 3.3-5.0 V
- Supply current: 100 mA
- Output format for the QTR-8A: 8 analog voltages ranging from 0 V to supplied voltage
- Output format for the QTR-8RC: 8 digital I/O-compatible signals that can be read as a timed high pulse
- Optimal sensing distance: 0.125″ (3 mm)
- Maximum recommended sensing distance for the QTR-8A: 0.25″ (6 mm)
- Maximum recommended sensing distance for the QTR-8RC: 0.375″ (9.5 mm)
- Weight without header pins: 0.11 oz (3.1 g)



PHYSICAL CHARACTERISTICS

Both the QTR-8A and QTR-8RC have the same physical characteristics. Each array measures 2.95″ long by 0.50″ wide and has a maximum thickness of approximately 0.125″.

Without header pins, the unit weighs 0.11 oz (3.1 g).

The individual reflectance sensors are distributed evenly on the board at 0.375″ intervals. The mounting holes are intended for #2 screws.

Distinguishing the QTR-8A from the QTR-8RC

The QTR-8A sensor array has a different output format from the QTR-8RC, so it is important you know which sensor model you have. What distinguishes one model from another are the components placed on a common PCB. The pictures below show the two models:

AUGURIES OF INNOCENCE

“To see a World in a Grain of Sand

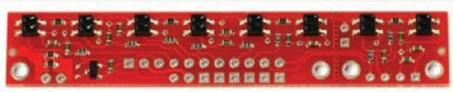
And a Heaven in a Wild Flower

Hold Infinity in the palm of your hand

And Eternity in an hour”

By William Blake (1757.-1827.) - an English poet, painter, and printmaker.

We should tend to spread knowledge not only via different technical fields but via other fields such as humanistic ones; arts, philosophy etc. The complexity of a system lies in its diversity rather than monodisciplinity!



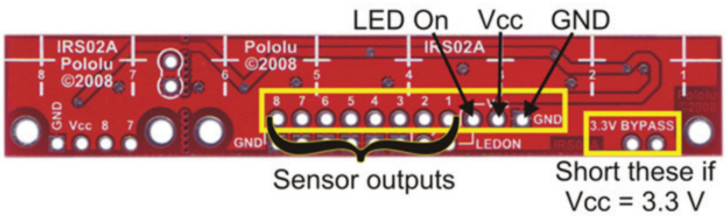
QTR-8A reflectance sensor array.

QTR-8RC reflectance sensor array.

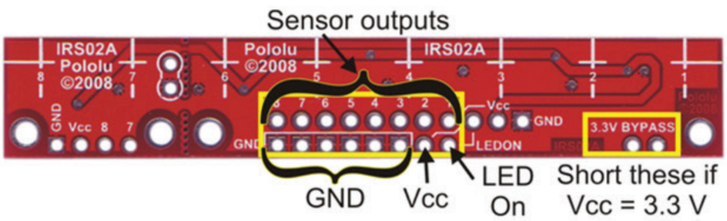
The QTR-8A uses a voltage divider for each sensor's output while the QTR-8RC uses an RC circuit. This produces the most visible difference between the two: eight 47k voltage divider resistors (black components with "473" written on them in yellow) on the QTR-8A are replaced by capacitors (tan components) on the QTR-8RC.

Module Connections

The QTR-8x reflectance sensor arrays are designed to provide some connection flexibility. The pins are standard 0.1" spacing and are arranged to support connection using either an 11×1 header strip or an 8×2 header strip. A 25-pin 0.1" header strip is included with the module; you can break this strip into smaller strips and solder them as desired, or you can solder wires directly to the unit for a more compact installation. The two connection methods are pictured below:



QTR-8x reflectance sensor array with 11×1 connection pins labeled.



QTR-8x reflectance sensor array with 8×2 connection pins labeled.

Several pins appear in multiple locations, but you can leave duplicate connection points disconnected. For example, you do not need to connect ground to all six ground pins along the lower edge of the board. Duplicate pins exist so that you can choose the most convenient points to make your connections.

Vcc, GND, and 3.3V BYPASS

The Vcc and GND pins are where the sensor array receives its power. Your Vcc connection must be between 3.3 and 5 V and must be able to supply at least 100 mA. The sensor's outputs will be relative to GND.
The module is calibrated so that its IR LEDs will achieve optimal brightness when Vcc is 5 V; using a lower Vcc will decrease the LED brightness or cause them to turn off completely. You can compensate for this by shorting the two 3.3V BYPASS pins together, which bypasses one stage of the LED current-limiting resistors and increases LED brightness.

Note: Do not short the 3.3V BYPASS pins together while using a Vcc of 5 V. While this would make the LEDs even brighter, it would exceed their current rating and put them at risk of burning out.

LEDON

This pin is connected to a MOSFET that delivers power to the IR LEDs, so its state determines the whether the LEDs are on or off. When this pin is driven high or left disconnected (it is internally pulled high), the LEDs are all on; when this pin is driven low, the LEDs are off. You can use this pin to save power by turning the LEDs off while you are not taking a reading. Additionally, you can connect this pin to a high-frequency PWM to control effective LED brightness and decrease power consumption.

QTR-8A Sensor Outputs

The QTR-8A reflectance sensor array has eight distinct sensor outputs, one from each LED/phototransistor pair.

These outputs are analog voltages ranging from 0 V to Vcc (which must be between 3.3 and 5 V). With a strong reflectance, such as when the sensor is over a white surface, its output voltage will tend towards 0 V; with very weak reflectance, such as when the sensor is over a black surface, its output voltage will tend towards Vcc. To get a good range of readings between white and black surfaces, we recommend you mount your sensor no more than 0.25" away from the surface. In our tests, the optimal distance between the sensor and the surface has been 0.125". Please see our.

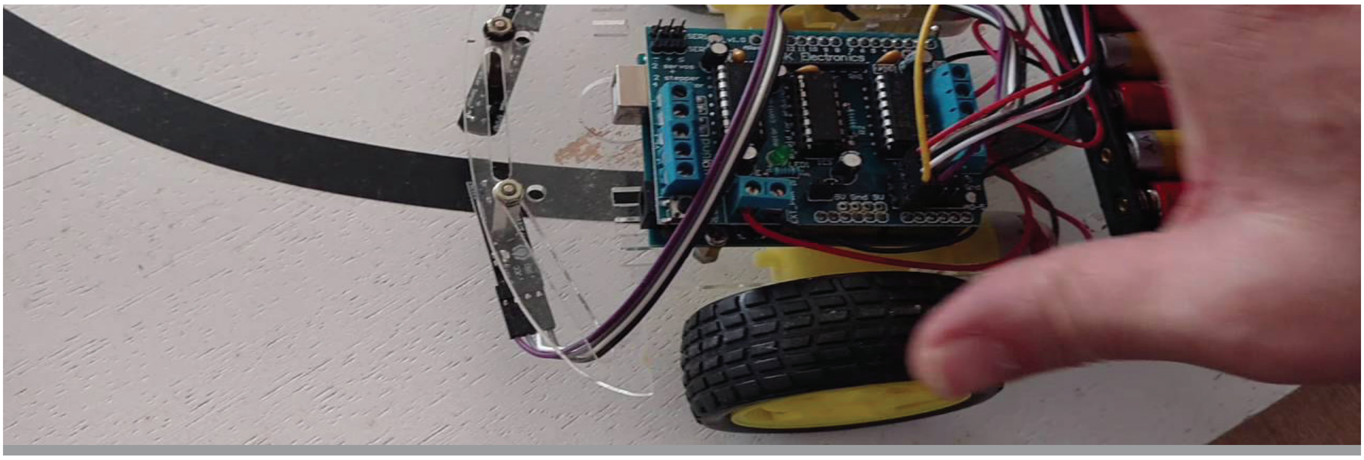
QTR-8RC Sensor Outputs

The QTR-8RC reflectance sensor array also has eight distinct sensor outputs, one from each LED/phototransistor pair.

In the 8RC sensor model, each phototransistor uses a capacitor discharge circuit that allows a digital I/O line on a microcontroller to take an analog reflectance reading by timing how long it takes the output voltage to decay due to the phototransistor. This format has several advantages over the 8A sensor model:

- No analog-to-digital converter (ADC) is required
- Improved sensitivity over voltage-divider analog output
- Parallel reading of all eight sensors is possible with most microcontrollers
- Parallel reading allows optimized use of LED power enable option

When you have a microcontroller digital I/O connected to a sensor output, the typical sequence for reading that sensor is:



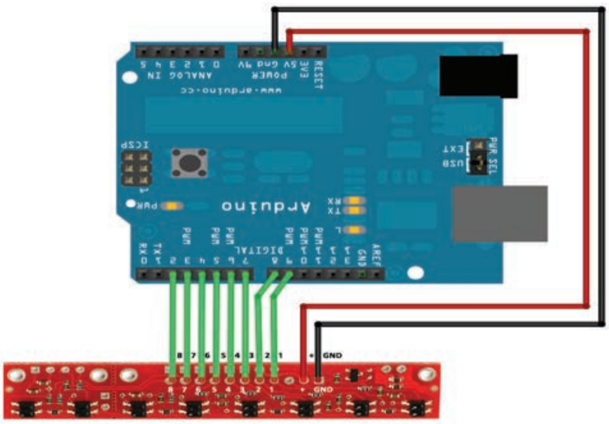
1. Turn on IR LEDs (optional).
2. Set the I/O line to an output and drive it high.
3. Allow at least 10 μs for the sensor output to rise.
4. Make the I/O line an input (high impedance).
5. Measure the time for the voltage to decay by waiting for the I/O line to go low.
6. Turn off IR LEDs (optional).

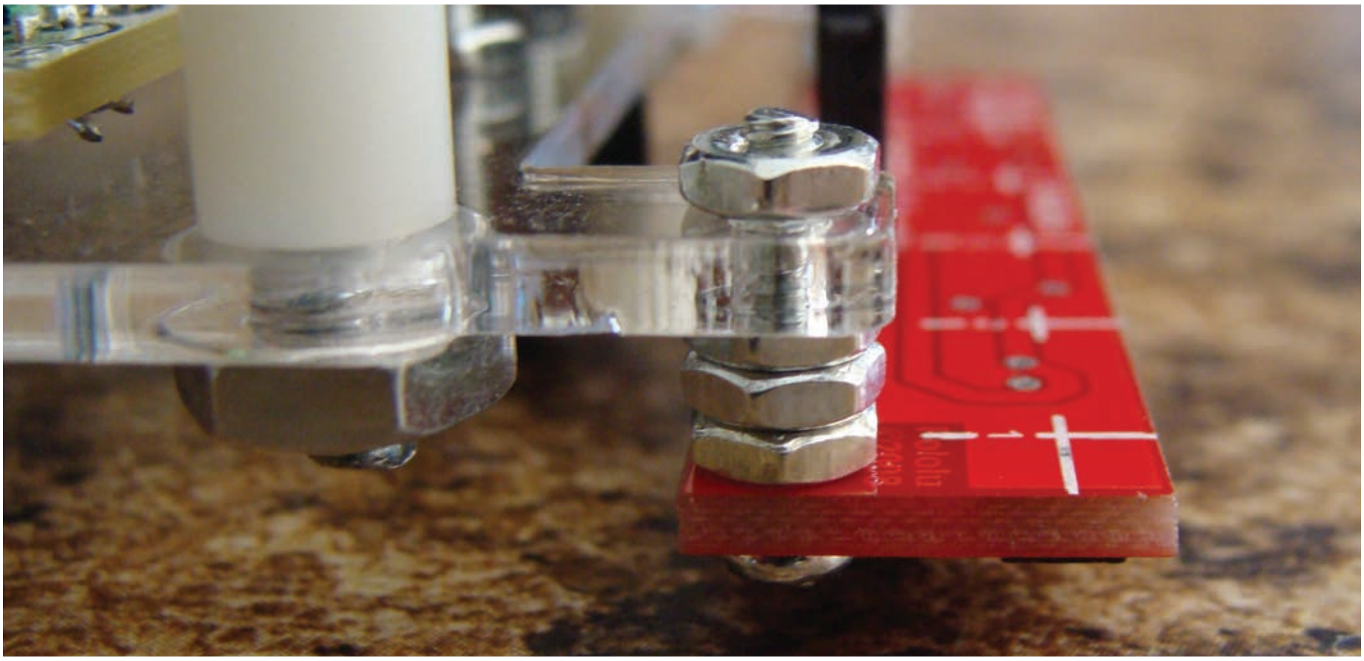
These steps can typically be executed in parallel on multiple I/O lines.
With a strong reflectance, such as when a sensor is over a white surface, the decay time can be as low as several dozen microseconds; with very weak reflectance, such as when the sensor is over a black surface, the decay time will typically be a few milliseconds, but can be several dozen milliseconds in the worst case. The exact time of the decay depends on your microcontroller's I/O line characteristics. Meaningful results can be available within 1 ms in typical cases (i.e. when not trying to measure subtle differences in low-reflectance scenarios), allowing up to 1 kHz sampling of all 8 sensors. If lower-frequency sampling is sufficient, substantial power savings can be realized by using the LEDON pin to turn off the LEDs. For example, if a 100 Hz sampling rate is acceptable, the LEDs can be off 90% of the time, lowering average current consumption from 100 mA to 10 mA.
If you want to achieve high frequency sampling rates, we recommend you mount your sensors 0.125" away from the surface. The greater your distance from the surface, the lower the overall reflectance will be, which in turn will result in longer decay times. We recommend you mount your sensors no more than 0.375" away from the surface.

If you are operating at a Vcc of 3.3 V, short those two pins together with a piece of wire. With a connection in place between these two pins, the two-sensor board will function. After the separation, sensor outputs 7 and 8 on the six-sensor board will no longer provide any signals.

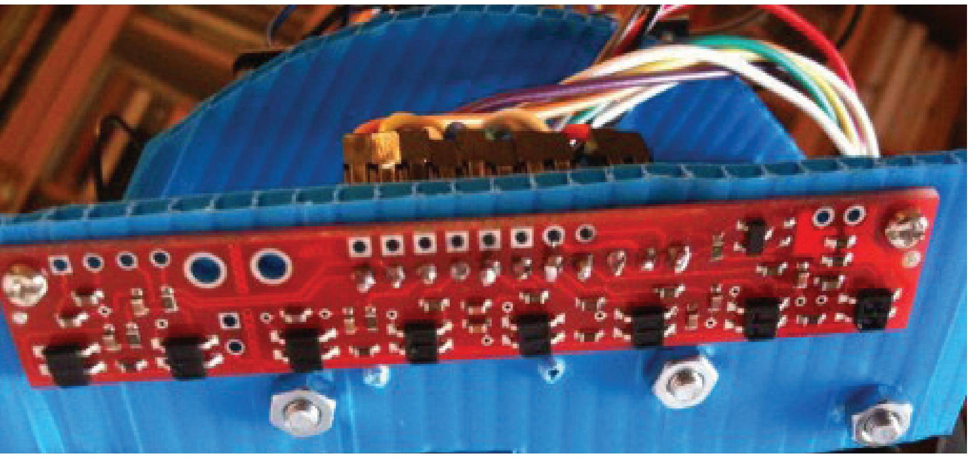
Additional Considerations

As the sensing distance of your sensors increases, the distinction between black and white surfaces starts to decrease. This problem can be exacerbated by infrared components of ambient lighting. The QTR-8x PCB was designed to help shield the sensors from ambient IR, but this may not be sufficient for areas with unusually high ambient IR or in cases where you need to mount your QTR-8x higher than the recommended 0.25" maximum. In these situations, you might fight it helpful to use shielding (e.g. a skirt around your robot) to block ambient IR.
When troubleshooting your QTR-8x, a digital camera can be useful in determining whether the IR LEDs are functioning as expected. Many older/cheaper digital cameras lack IR filters (most cell phone cameras fit in this category) and can therefore be used to determine if the LEDs are on or off. However, some cameras (usually more expensive ones) have better filters that block IR.





Arduino Library for the Pololu QTR Reflectance Sensors.



The libraries will give you everything you need to interface with a QTR-8x reflectance sensor array or multiple QTR-1x reflectance sensors, including advanced features like automatic calibration and, in the case of line detection, calculation of the line's position.

Library Installation

If you are using version 1.6.2 or later of the Arduino software, you can use the Library Manager to install this library.

In the Arduino IDE, open the "Sketch" menu, select "Include Library", then "Manage Libraries…".

1. Search for "QTRSensors".

2. Click the QTRSensors entry in the list.

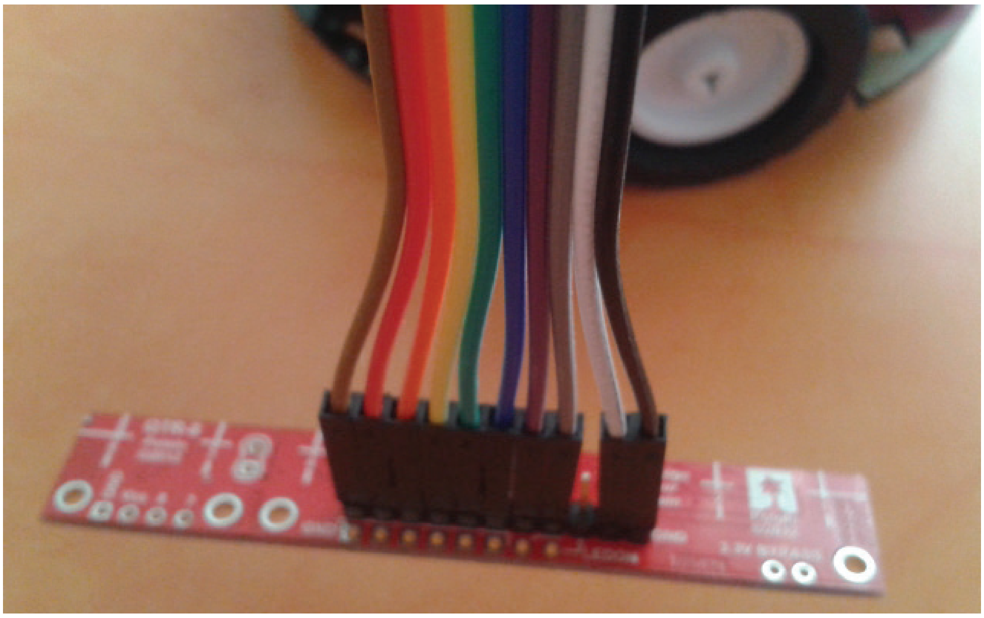
3. Click "Install".

If this does not work, you can manually install the library:

1. Download the latest release archive from GitHub and decompress it.

2. Rename the folder "qtr-sensors-arduino-xxxx" to "QTRSensors".

3. Drag the "QTRSensors" folder into the "libraries" directory inside your Arduino sketchbook directory. You



can view your sketchbook location by opening the “File” menu and selecting “Preferences” in the Arduino IDE. If there is not already a “libraries” folder in that location, you should make the folder yourself.

4. After installing the library, restart the Arduino IDE.

You should now be able to use these libraries in your sketches by selecting Sketch > Import Library > QTRSensors from your Arduino IDE (or simply type #include <QTRSensors.h> at the top of your sketch). Note that you might need to restart your Arduino IDE before it sees the new libraries.
Once this is done, you can create a QTRSensorsAnalog object for your QTR-xA sensors and a QTRSensorsRC object for your QTR-xRC sensors:

This library takes care of the differences between the QTR-xA and QTR-xRC sensors internally, providing you with a common interface to both sensors. The only external difference is in the constructors. The first argument to the QTRSensorsAnalog constructor is an array of analog input pins (0 – 7) while the first argument to the QTRSensorsRC constructor is an array of digital pins (0 – 19).

Note that analog inputs 0 – 5 can be used as digital pins 14 – 19.

The only other difference you might experience is in the time it takes to read the sensor values. The QTR-xRC sensors can all be read in parallel, but each requires the timing of a pulse that might take as long as 3 ms (you can specify how long the library should time this pulse before timing out and declaring the result full black). The QTR-xA sensors use the analog-to-digital converter (ADC) and hence must be read sequentially. Additionally, the analog results are produced by internally averaging a number of samples for each sensor (you can specify the number of samples to average) to decrease the effect of noise on the results.

Several example sketches are available to help you get started. To view the example sketches, open the Arduino IDE and navigate to:

File > Examples > QTRSensors

As a first step, you can use QTRARawValuesExample (for QTR-xA sensors) or QTRRCRawValuesExample (for the QTR-xRC sensors). These examples will simply print the raw readings from the sensors to the serial monitor, using 9600 baud. Once that is working, youmight want to try one of the more advanced examples, QTRAExample or QTRRCExample, which incorporate calibration and also estimate the position of a line.

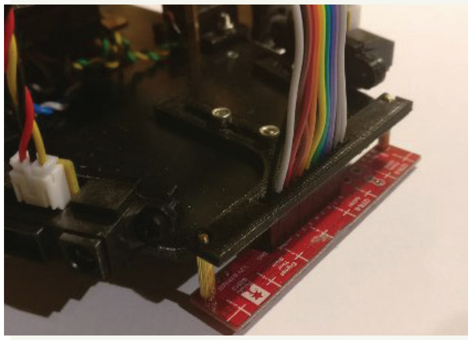
QTRSENSORS

METHODS & USAGE

NOTES

Calibration

This library allows you to use the calibrate() method to easily calibrate your sensors for the particular conditions it will encounter. Calibrating your sensors can lead to substantially more reliable sensor readings, which in turn can help simplify your code since. As such, we recommend you build a calibration phase into your application’s initialization routine. This can be as simple as a fixed duration over which you repeated call the calibrate() method. During this calibration phase, you will need to expose each of your reflectance sensors to the lightest and darkest readings they will encounter. For example, if you have made a line follower, you will want to slide it across the line during the calibration phase so each sensor can get a reading of how dark the line is and how light the ground is.



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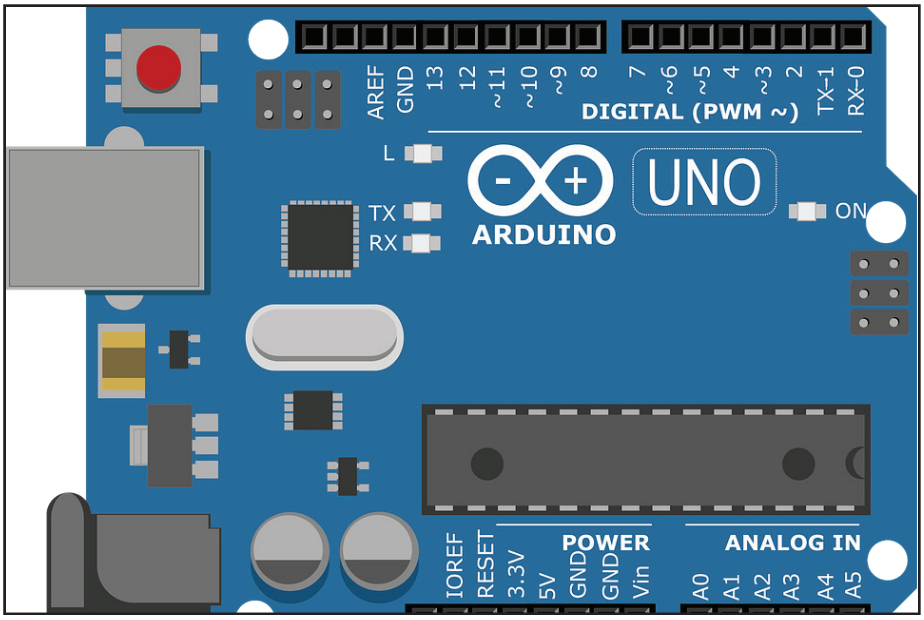


Arduino is an open-source electronics platform based on easy-to-use hardware and software.

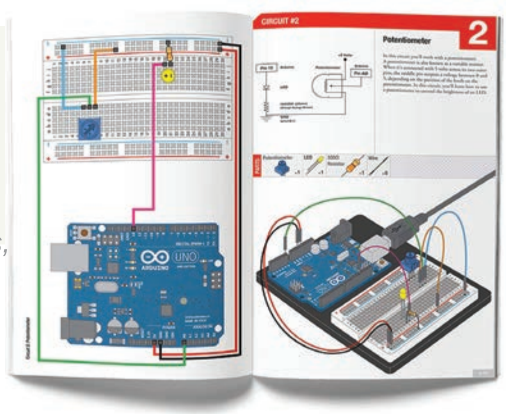
WHAT IS ARDUINO?

Microcontrollers have existed since many years. Every automation in home or industry has some type of microcontroller inside.

Arduino is, in essence, another microcontroller. Yet, it has some special facts:

- It's open-source
- It's easy to use.
- It's cheap
- It has a huge community contributing with free software and hardware.
- It can be programmed in a “C like” language,
- There are optional programming environments, like Scratch.
- No special training hardware or assembler knowledge neede.
- It can be connected to computers via USB.
- Free multi-platform IDE to program Arduino.

Arduino is not only a board with a microcontroller, it's a world-wide movement, a essential part of the ecosystem of free software and hardware and a way of thinking. For those reasons, Arduino is one of the best tools for teaching electronics, robotics or programming. It’s very suitable for ESTEAM projects obviously for the technology side, but also because it’s inclusive for the price and the learning curve. And there are many online resources for making art with this ecosystem.



You can find resources, manuals, tutorials and anything you need to start with Arduino in https://www.arduino.cc/ . We recommend to visit the project hub (https://create.arduino.cc/projecthub) to search for similar projects.

Also, we recommend the official forum: https://forum.arduino.cc/ .

ARDUINO BOARD
Arduino senses the environment by receiving inputs from many sensors, and affects its surroundings by controlling lights, motors, and other actuators.

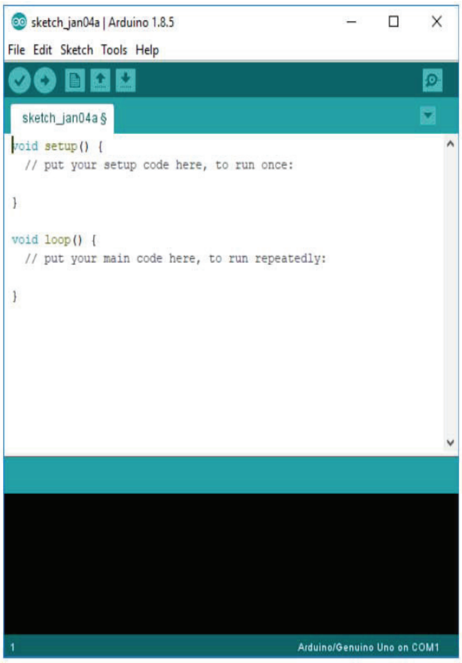
GETTING STARTED.

In other manuals of this project there are recommendations for different hardware. But to start, we only need a computer, an Arduino UNO, a LED and an USB wire.

First we need to download the Arduino IDE https://www.arduino.cc/en/Main/Software#download

Each Operating System has his own method to install the software, but It's very easy and we can find instructions here: https://www.arduino.cc/en/Guide/HomePage

Once Arduino IDE is working, we can see a simple text editor similar to the processing language editor.



The first thing we can do is to create our first sketch and upload it to the board. To do so, we need to have it connected to the computer.

If you are using Windows, maybe you need to install a controller from this web: https://www.arduino.cc/en/guide/windows

If you are using Macintosh or Linux, you don't need to install anything. The port is a COM port and you can find it in devices manager.

In the Arduino IDE you can choose the correct device from Tools > Port and check if it's correct in Tools > Get Board Info.

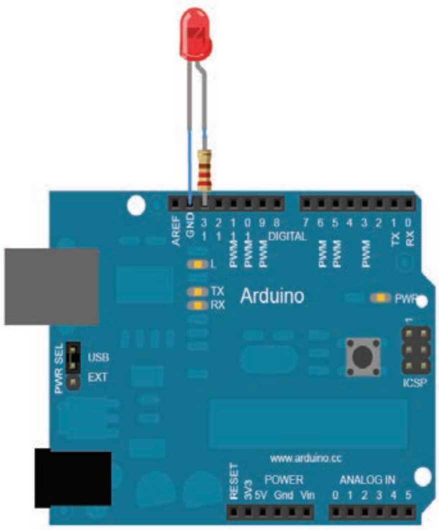
We won't do a troubleshooting manual, but if you run into problems, you can search in Internet and find every solution to any error message.

```
const int LED  = 13;

void setup() {

// initialize digital pin LED as an output.

pinMode (LED , OUTPUT);

 }

// the loop function runs over and over again forever

void loop() {

  digitalWrite (LED , HIGH);

 // turn the LED on (HIGH is the voltage level)

  delay (1000);

 // wait for a second

  digitalWrite (LED , LOW);

 // turn the LED off by making the voltage LOW

  delay (1000);

 // wait for a second

}
```

THE ARDUINO "HELLO WORLD"

Arduino is an interactive device. It can sense the environment (sensors), process this information and interact with the environment, the Internet or the user (actuators, serial port...).

The typical first project with Arduino is to make a LED blink. You can connect the LED to the digital port 13 and GND. Remember that the short wire is the cathode and the long is the anode of the LED.



As you can see, programming for Arduino is not difficult because there are lots of things simplified. Let's take a look:

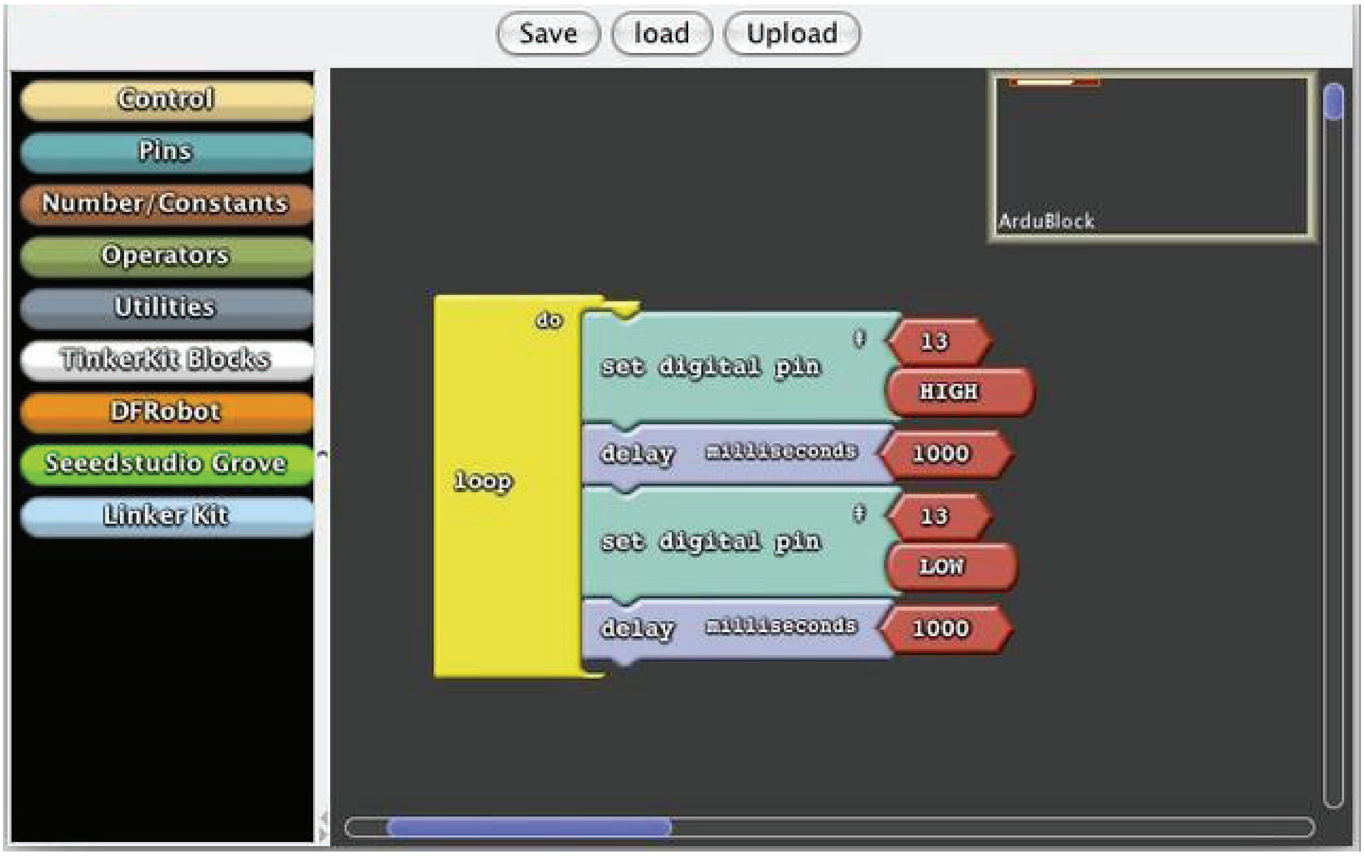
- We have a setup function to initialize Arduino pins.
- We have a loop function that will run forever while the board is connected to a power supply.
- In this sketch, we have set a variable called LED with the number 13.
- In the setup function we have set the 13 pin as an OUTPUT pin. Digital pins can be INPUT or OUTPUT.
- OUTPUT, INPUT, HIGH and LOW are constants in the Arduino language.
- The function digitalWrite() is provided by Arduino language to manipulate digital pins.

Next, you have to verify the code with the check button. If it is correct, you can upload the sketch to the Arduino board with the arrow button. While uploading, the onboard LED and your LED will blink rapidly. When the upload is complete and the program starts, the LED will blink with one second period.

Otherlanguages

For a computer science teacher, it's not difficult to program with the official IDE of Arduino. But, for students or other type of teachers, there are other easier alternatives.

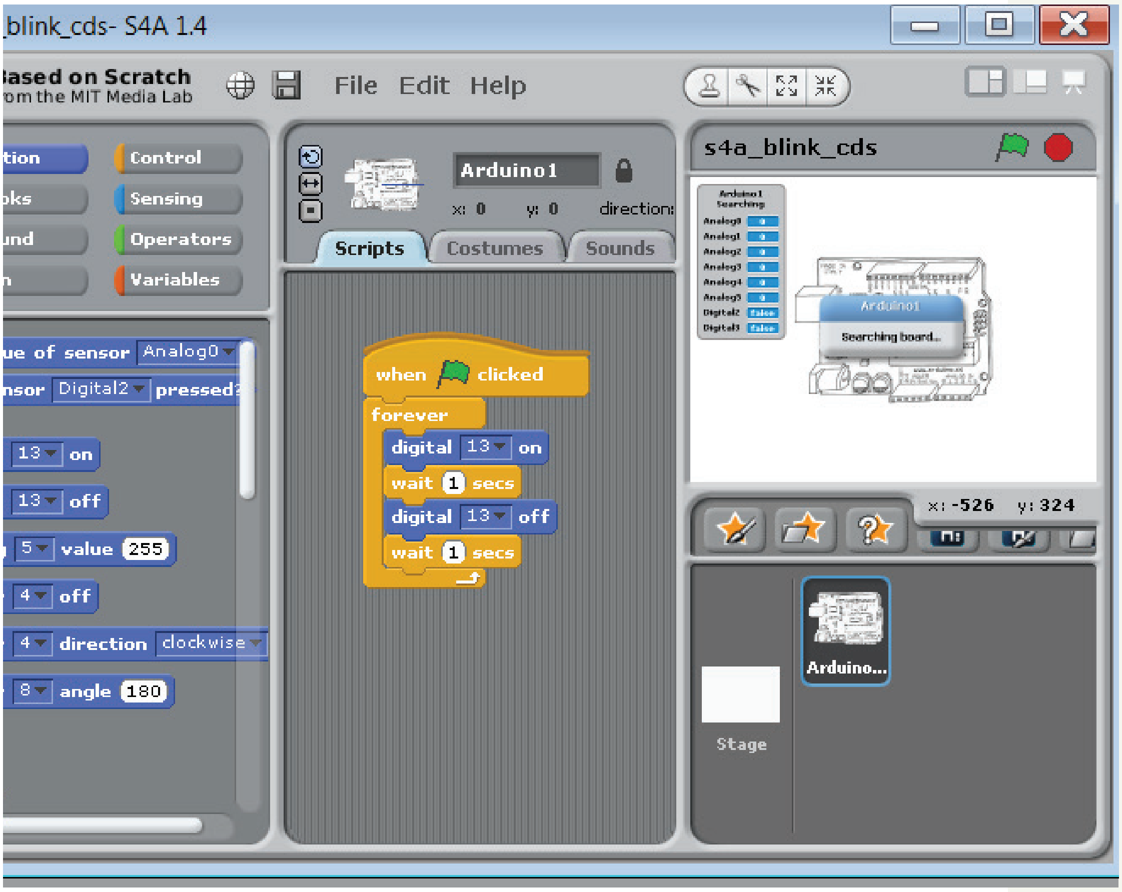
Ardublock The first alternative could be Ardublock (http://blog.ardublock.com/). It's a block editor like Scratch, but it can be installed as a plug-in for the arduino IDE. Let's see the example below made using this language:



S4A

We also recommend Scratch for Arduino or S4A (http://s4a.cat/index.html) it is a modification of Scratch making it compatible with Arduino. You need to install a program and a firmware in Arduino to communicate with the program. SA4 is very easy and powerful, and students might be familiarized with Scratch before.

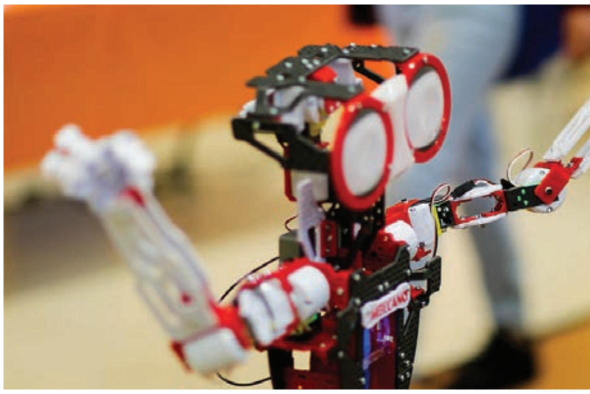
The blink led example can be programmed in the following way:



Ardublock or S4A are very good alternatives to text programming, but robots could be complicated and if you are thinking in competition where time is important, there is nothing as fast as text code.

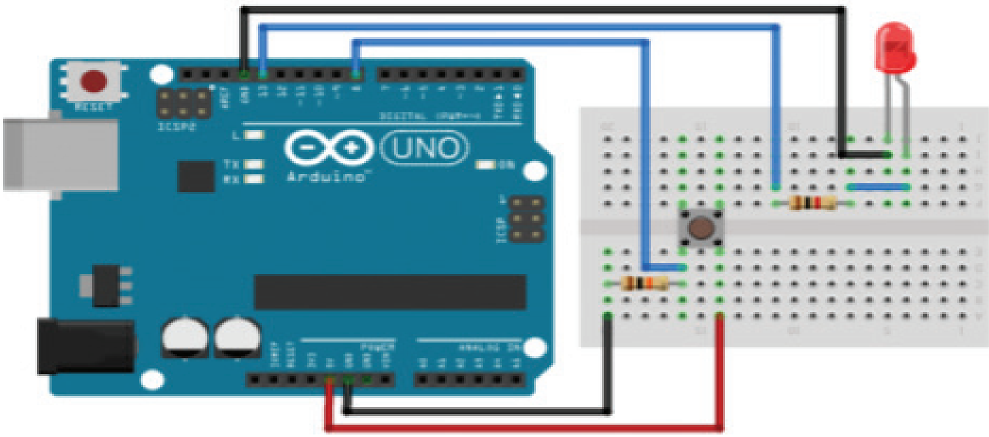
So we recommend to use the official Arduino IDE.

"S4A differs quite a bit from ArduBlock. It uses a firmata-type of protocol to interface between actual executed code and the Scratch program you've drawn up. There are pros and cons there: Written code takes effect instantly, but you're always tethered to the USB port. For any kids who are already better Scratch creators than I'd ever be (which is a lot, judging by what we're seeing on the tour), S4A is a perfect sidestep over into the physical world."



Push Buttons

In this example, we are going to control the behaviour of a LED with a button. You can make this circuit with your protoboard:



You need a protoboard, a LED, a button and a 10K Ohm resistor.

If you want to light the LED when you push the button:

```
// constants won't change. They're used here to set pin numbers:
const int button  =  8 ;            // the number of the pushbutton pin
const int led  =  13 ;              // the number of the LED pin
// variables will change:
int buttonState  =  0 ; // variable for reading the pushbutton status

void setup() {
  // initialize the LED pin as an output:
  pinMode (led , OUTPUT);
  // initialize the pushbutton pin as an input:
  pinMode (button , INPUT); }

void loop() {
  // read the state of the pushbutton value:
  buttonState  = digitalRead (button);
  // check if the pushbutton is pressed.  If it is, the buttonState is HIGH:
  if  (buttonState == HIGH ) {
          // turn LED on:
          digitalWrite (led , HIGH);
  } else {
 // turn LED off:
 digitalWrite (led , LOW);
  }
}
```

You can see various new things:

- A variable (buttonState) to read the button status.
- A pin set to INPUT mode.
- The digitalRead() function to set the variable buttonState.

In the following example, you don't need to change the circuit, only the program. The goal is to toggle the LED when pressing the button. This problem is interesting because it involves not only programming, but dealing with physical variables that the programmer can not control: push time and the electric imperfections of the button. An only programing approach could take different lectures of the button and the result could be unpredictable. This is one of the official examples of Arduino to solve it:

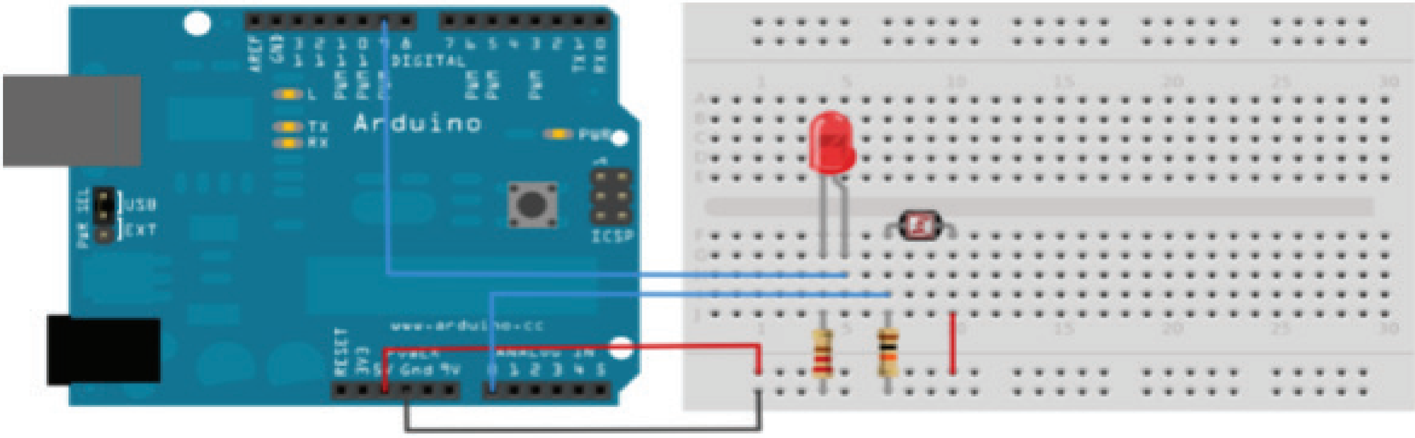
```
const int buttonPin  =  2 ;   // the number of the pushbutton pin
const int ledPin  = 13 ;    // the number of the LED pin

int ledState  = HIGH ;     // the current state of the output pin
int buttonState ;            // the current reading from the input pin
int lastButtonState  = LOW ;   // the previous reading from the input pin

// the following variables are unsigned longs because the time, measured in
// milliseconds, will quickly become a bigger number than can be stored in an int.
unsigned long lastDebounceTime  =  0 ;      // the last time the output pin was toggled
unsigned long debounceDelay  = 50 ; // the debounce time; increase if the output flickers

void setup() {
  pinMode (buttonPin , INPUT);
  pinMode (ledPin , OUTPUT);
  // set initial LED state
  digitalWrite (ledPin , ledState);
 }

void loop() {
  // read the state of the switch into a local variable:
  int reading  = digitalRead (buttonPin);
  // check to see if you just pressed the button
  // (i.e. the input went from LOW to HIGH), and you've waited long enough
  // since the last press to ignore any noise:
 // If the switch changed, due to noise or pressing:
  if  (reading != lastButtonState ) {
          // reset the debouncing timer
         lastDebounceTime  = millis();
  }
 if ((millis()  - lastDebounceTime )  > debounceDelay ) {
 // whatever the reading is at, it's been there for longer than the debounce
 // delay, so take it as the actual current state:
 // if the button state has changed:
 if  (reading != buttonState ) {
  buttonState  = reading;
  // only toggle the LED if the new button state is HIGH
  if  (buttonState == HIGH ) {
ledState  =   !ledState;
 }
 }
  }
  // set the LED:
  digitalWrite (ledPin , ledState);
  // save the reading. Next time through the loop, it'll be the lastButtonState:
  lastButtonState  = reading;
 }
```

The example above is crucial, because not only you have to think in solving the algorithm, you also have to control the hard world of the hardware.

Sensors

There are many types of sensors for the arduino, we'll explore through the most useful ones
Light sensor: A LDR is a light sensor that works as a resistor. When the ambiance is dark, the resistance is very high, when the ambiance is lighted, the LDR is a good conductor.

For the next example, you need to build this circuit:



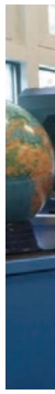

```
int sensorPin  = A0 ; // select the input pin for the potentiometer
int ledPin  =  9 ; // select the pin for the LED
int sensorValue  =  0 ;  // variable to store the value coming from the sensor

void setup() {
  // declare the ledPin as an OUTPUT:
  pinMode (ledPin , OUTPUT);
 }

void loop() {
  // read the value from the sensor:
  sensorValue  = analogRead (sensorPin);
  // turn the ledPin on
 digitalWrite (ledPin , HIGH);
  // stop the program for <sensorValue> milliseconds:
 delay (sensorValue);
  // turn the ledPin off:
  digitalWrite (ledPin , LOW);
  // stop the program for for <sensorValue> milliseconds:
  delay (sensorValue);
 }
```

You can find some new things:

- An analog pin (A0).
- An analogRead() function to get the sensor readout and set the sensorValue variable.

We are going to set the intensity of the light for the LED depending on the LDR. You don't have to change the circuit.
Remember that the 3,5,6,9,10 and 11 pins are digital pins with PWM* to simulate analog output.
The code is

```
int sensorPin  = A0 ; // select the input pin for the potentiometer
int ledPin  =  9 ; // select the pin for the LED
int sensorValue  =  0 ;  // variable to store the value coming from the sensor

void setup() {
  // declare the ledPin as an OUTPUT:
  pinMode (ledPin , OUTPUT); }
```



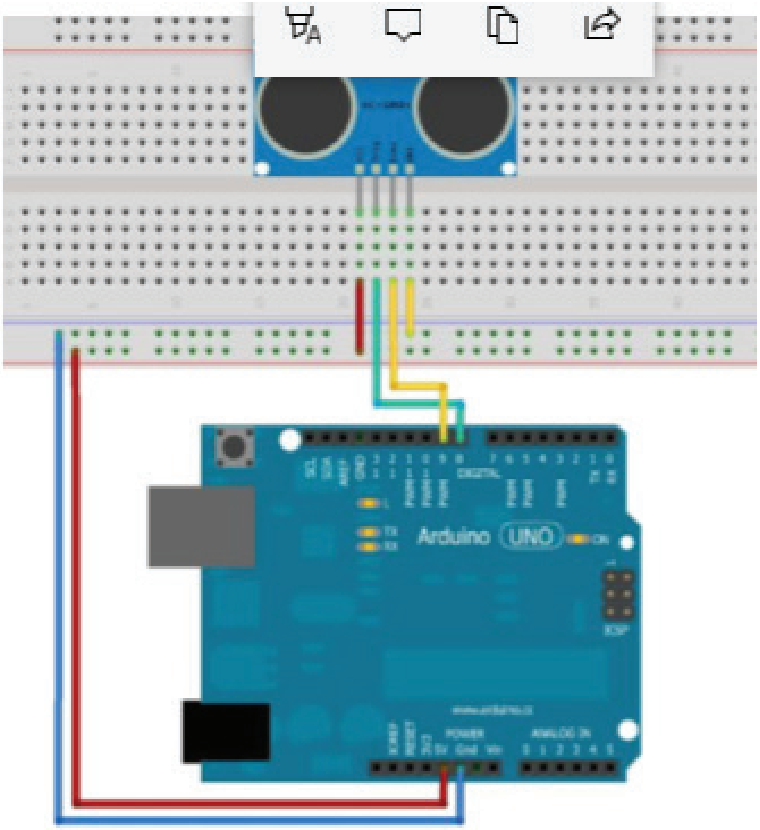
```
void loop() {
   // read the value from the sensor:
   sensorValue  = analogRead (sensorPin);
   analogWrite (ledPin , sensorValue/4);
  delay (10);
}
```

PWM: A digital output can change the state very quickly, so quickly that we can't see the change. But if we connect a LED to this pin, we can see less light. This is called "Pulse With Modulation" Arduino simplifies the code providing some pins with PWM and we only have to call the function analogWrite()

Ultrasonic Sensor

Like bats do, the ultrasonic sensor uses sonar to determine the distance to an objects. It can't be affected by solar light or black materials. It is very accurate and stable.

For using the sensor you need a circuit like this:



And the code for testing the Ultrasonic sensor is very simple:

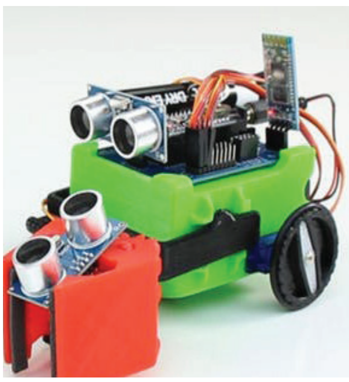
```
const int trigPin  = 8;
const int echoPin  = 9;
 // defines variables
long duration;
int distance;
void setup() {
            pinMode (trigPin , OUTPUT); // Sets the trigPin as an Output
            pinMode (echoPin , INPUT); // Sets the echoPin as an Input
          Serial .begin (9600); // Starts the serial communication
 }
void loop() {
    // Clears the trigPin
    digitalWrite (trigPin , LOW);
    delayMicroseconds ( 2);
   // Sets the trigPin on HIGH state for 10 micro seconds
   digitalWrite (trigPin , HIGH);
   delayMicroseconds (10);
   digitalWrite (trigPin , LOW);
   // Reads the echoPin, returns the sound wave travel time in microseconds
   duration  = pulseIn (echoPin , HIGH);
   // Calculating the distance
   distance = duration *0.034 /2;
   // Prints the distance on the Serial Monitor
   Serial .print ("Distance: ");
   Serial .println (distance);
}
```

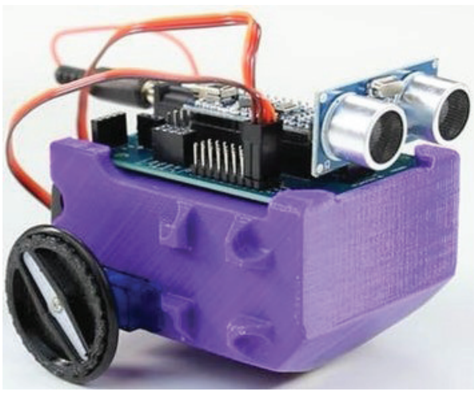
Here we have some new things:

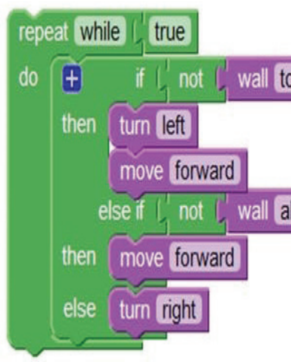
- We use two digital pins as input and output for the sonar.
- We use the Serial.begin and print to send the information to the computer.
- In the loop, we send 10 microseconds of sound to the trigPin (output).
- We then, use the pulseIn (https://www.arduino.cc/reference/en/language/functions/advanced-io/pulsein/) function to measure the duration of the sound that we are capturing.
- If the duration is long, the sound has taken more time to arrive and there are more distance. We can calculate the distance if we know the speed of sound (340m/s).

We can use this sensor in robots to avoid obstacles. Many robot makers put more than one sensor in various directions to improve the collision detection. You can also put a servo to rotate the sensor before decide where to go. This is explained later in this manual.

In order to simplify the sensor management, you can use the a ultrasonic.h library. There are many libraries. We recommend to use the library browser in Arduino IDE to find a good one. For example:







```
// Ultrasonic - Library for HR-SC04 Ultrasonic Ranging Module.
#include <Ultrasonic.h>

Ultrasonic ultrasonic ( 9 ,10); // (Trig PIN,Echo PIN)

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

void loop() {
  Serial .print (ultrasonic .Ranging (CM)); // CM or INC
  Serial .println (" cm" );
  delay (100);
}
```

QTR-8[A-RC] reflective sensor array.

Basic robots usually avoid obstacle and follow lines. To follow lines, a robot needs to use some infrared sensors to detect the different IR reflectance of the ground.

The QTR-8A outputs an analog voltage that can be measured by an analog-to-digital converter (ADC). The QTR-8RC outputs require a digital I/O line capable of driving the output line high and then measuring the time for the output voltage to decay to measure the reflectance. We recommend the QTR-8RC.

In order to use this sensor array, you need to use the library QTRSensors you can find by the menu Sketch>Include Library>Manage Libraries. If it doesn’t work you can download manually the library here: https://github.com/pololu/qtr-sensors-arduino/releases .

Once this is done, you can create a QTRSensorsRC object for your sensor:

```
// create an object for four QTR-xRC sensors on digital pins 0 and 9, and on analog
// inputs 1 and 3 (which are being used as digital inputs 15 and 17 in this case)
 QTRSensorsRC qtrrc((unsigned char[])  { 0 ,  9 , 15 , 17},  4);
```

The constructor needs an array of digital pins.

You can find some examples at File>Examples>QTRSensors. For example the QTRRCRawValuesExample, wich show the raw reading by the serial monitor.

Calibration Calibrating your sensors can lead to more reliable sensor readings. We recommend you to build a calibration phase into the initialization routine. It can be as simple as a repetition of the calibrate() method during a fixed time. During this calibration time, you need to expose each sensor to the lightest and darkest surfaces it will encounter.

```
#include <QTRSensors.h>
 // create an object for your type of sensor (RC)
// in this example we have three sensors on analog inputs 0 - 2, a.k.a. digital pins 14 - 16
QTRSensorsRC qtr((char[])  {14 , 15 , 16},  3);
void setup() {
 // optional: wait for some input from the user, such as  a button press
// then start calibration phase and move the sensors over both
// reflectance extremes they will encounter in your application:
int i;
for  (i  =  0 ; i  < 250 ; i++)  // make the calibration take about 5 seconds
  {
    qtr .calibrate();
    delay (20);
 }
  // optional: signal that the calibration phase is now over and wait for further
// input from the user, such as a button press
}
```

Reading the sensors

You can read the sensor values using the read() method or, if it is calibrated, the readCalibrated() method. With readCalibrated(), the values are from 0 (White) to 1000 (black).

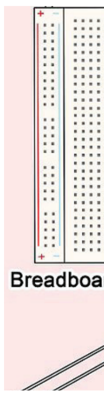
For line-detection, you can use the readLine() method. Which takes an optional parameter that indicates whether the line is white on black or black on white and a boolean that indicates whether the IR emitters should be on or off during the measurement. The result is 0 if the sensors detect that the line is on or outside of sensor 0 and returns 1000*(N-1) for each sensor. If whe use the QTR8-RC, the values will be 0, 1000, 2000, 3000, 4000, 5000, 6000, 7000 and 8000 depends on the position of the line.

Example of a rudimentary line following:

```
void loop()
{
   unsigned int sensors [ 3];
   // get calibrated sensor values returned in the sensors array,
   // along with the line position.
   // position will range from 0 to 2000,
    // with 1000 corresponding to the line over the middle sensor.
   int position  = qtr .readLine (sensors);
   // if all three sensors see very low reflectance,
    // take some appropriate action for this situation.
   if  (sensors [ 0 ]  > 750 && sensors [ 1 ]  > 750 && sensors [ 2 ]  > 750)
  {
   // do something.
    // Maybe this means we're at the edge of a course or about to fall off
    // a table, in which case, we might want to stop moving, back up, and turn around.
     return;
   }
    // compute our "error" from the line position.
   // We will make it so that the error is zero
   // when the middle sensor is over the line,
    // because this is our goal.  Error will range from
   // -1000 to +1000.
   // If we have sensor 0 on the left and sensor 2 on the right,  a reading of
   // -1000 means that we see the line on the left
   // and a reading of +1000 means we see the
   // line on the right.
   int error  = position  - 1000;
   int leftMotorSpeed  = 100;
   int rightMotorSpeed  = 100;
   if  (error  <  -500 )  // the line is on the left
        leftMotorSpeed  =  0 ;  // turn left
   if  (error  > 500 )  // the line is on the right
       rightMotorSpeed  =  0 ;  // turn right
   // set motor speeds using the two motor speed variables above
 }
```

This is the most simple example possible, but if you want a more accurate movements, you may need to use PID https://en.wikipedia.org/wiki/PID_controller

Arduino Motor shield



In order to make a robot, we need sensors and motors. The official Arduino Motor Shield is the one we recommend. It is not very expensive, compatible with Arduino Uno and you can find a lot of documentation about it.

A shield is a board that can be placed on top of the Arduino and whose connectors adapt perfectly in the Arduino Uno. The shield uses some of the pins of the Arduino and exposes all the other.

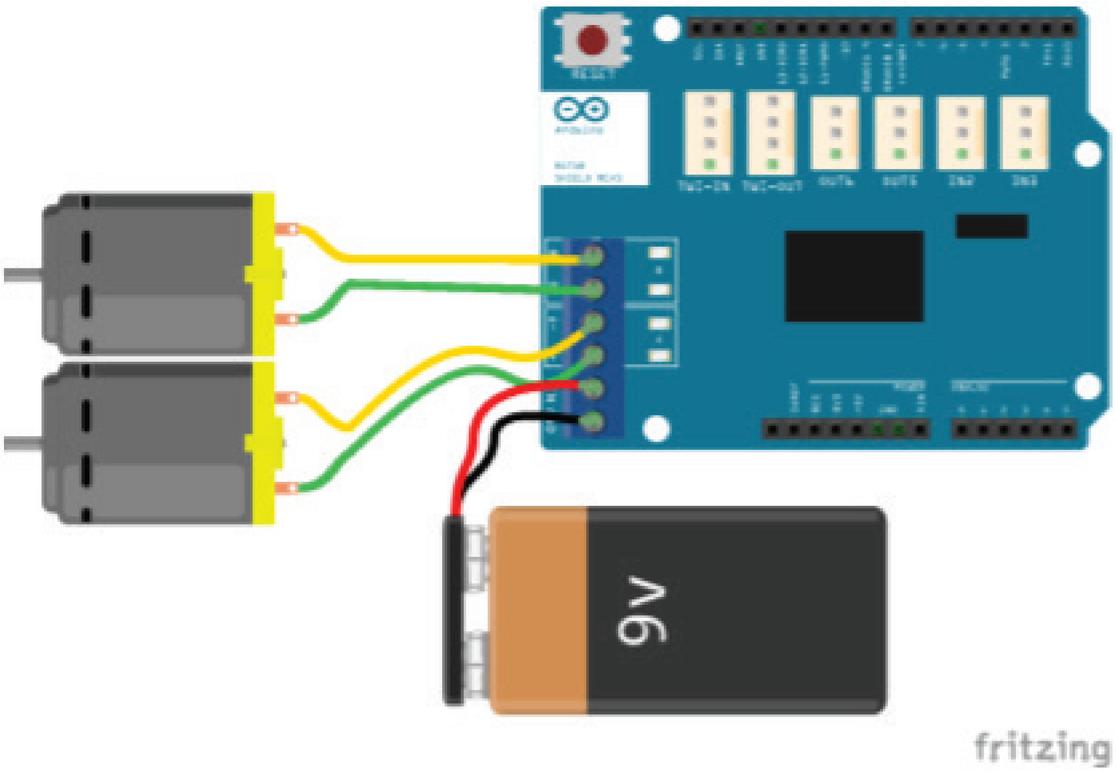
The technical specifications and how to mount it can be consulted here: https://store.arduino.cc/arduino-motor-shield-rev3

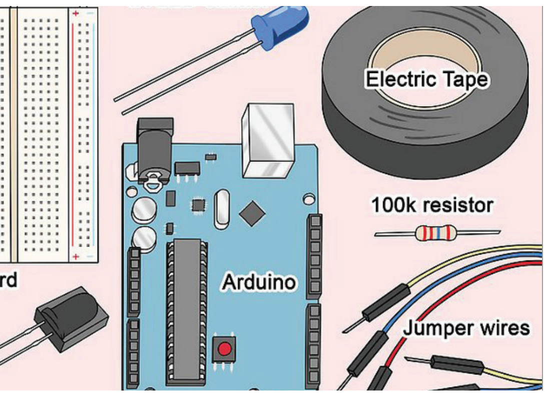
This shield has two separate channels, called A and B. Each one uses 4 of the Arduino pins to drive or sense the motor. In total, there are 8 pins used by this shield. You can use each channel separately to drive two DC motors or combine them to drive one bipolar stepper motor. The shield's pins, divided by channel are shown in the table below:

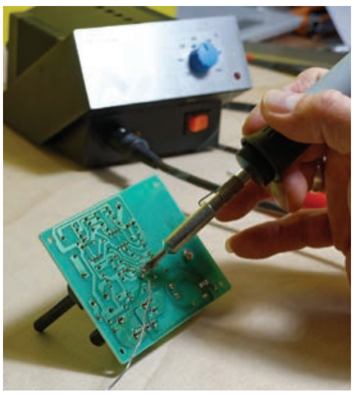
Function	pins per Ch. A	pins per Ch. B
Direction	D12	D13
PWM	D3	D11
Brake	D9	D8
Current Sensing	A0	A1

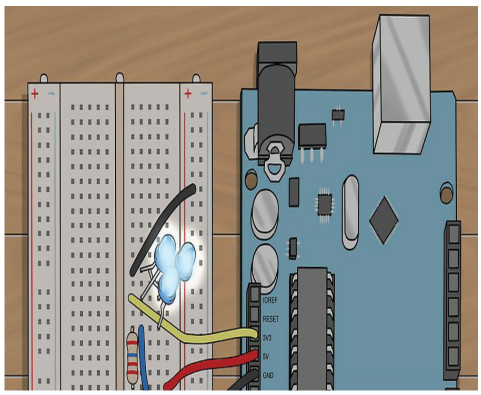
If you don't need the Brake and the Current Sensing and you also need more pins for your application, you can disable this features by cutting the respective jumpers on the back side of the shield.

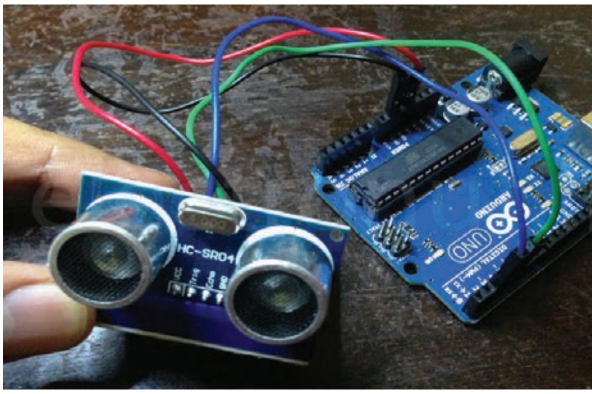
This schema shows the motor connections. The motor shield can power the Arduino board, but this is not recommended.











Push Buttons

Here you can see a basic code to show how to control motors with Arduino and the motor shield:

```
/*************************************************************
Motor Shield  2 -Channel DC Motor Demo by Randy Sarafan

For more information see: https ://www.instructables.com/id/Arduino-Motor-Shield-Tutorial/

*************************************************************/

void setup() {
  //Setup Channel A
  pinMode (12 , OUTPUT);  //Initiates Motor Channel A pin
  pinMode ( 9 , OUTPUT); //Initiates Brake Channel A pin
 //Setup Channel B
  pinMode (13 , OUTPUT); //Initiates Motor Channel A pin
  pinMode ( 8 , OUTPUT);  //Initiates Brake Channel A pin
 }

void loop(){
  //Motor A forward @ full speed
  digitalWrite (12 , HIGH); //Establishes forward direction of Channel A
 digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
 analogWrite ( 3 , 255);   //Spins the motor on Channel A at full speed
 //Motor B backward @ half speed
  digitalWrite (13 , LOW);  //Establishes backward direction of Channel B
  digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
  analogWrite (11 , 123); //Spins the motor on Channel B at half speed
  delay (3000);
  digitalWrite ( 9 , HIGH);  //Engage the Brake for Channel A
  digitalWrite ( 8 , HIGH);  //Engage the Brake for Channel B
  delay (1000);     //Motor A backward @ full speed
 digitalWrite (12 , LOW);  //Establishes backward direction of Channel A
 digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
 analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
  //Motor B forward @ full speed
  digitalWrite (13 , HIGH); //Establishes forward direction of Channel B
  digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
  analogWrite (11 , 255);   //Spins the motor on Channel B at full speed
  delay (3000);
  digitalWrite ( 9 , HIGH);  //Engage the Brake for Channel A
  digitalWrite ( 8 , HIGH);  //Engage the Brake for Channel B
  delay (1000);
 }
```

Avoiding obstacles with Arduino robot

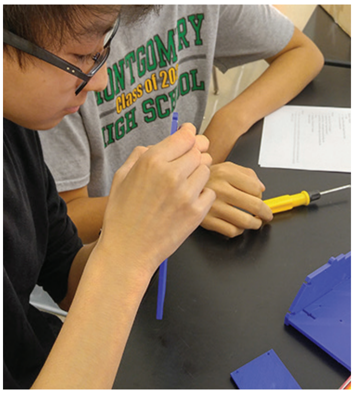
We can combine the sonar sensor with the motor shield to make a robot that can avoid obstacles. This demonstration is only about avoiding obstacles with a two motors robot, but you may need to add some “intelligence” to avoid obstacles and reach a goal.

This is the example of a simple robot that avoid obstacles with a fixed ultrasonic sensor:

```
#include "Ultrasonic.h"

Ultrasonic ultrasonic (A0 ,A5);

long microsec  = 0;
float distanceCM  = 0;

void setup() {
   Serial .begin (9600);
     //Setup Channel A
   pinMode (12 , OUTPUT); //Initiates Motor Channel A pin
   pinMode ( 9 , OUTPUT); //Initiates Brake Channel A pin
   //Setup Channel B
   pinMode (13 , OUTPUT); //Initiates Motor Channel A pin
   pinMode ( 8 , OUTPUT);  //Initiates Brake Channel A pin

}
 void loop() {
   microsec  = ultrasonic .timing(); // reading the sensor
 //convert the distance to cm
   distanceCM  = ultrasonic .convert (microsec ,Ultrasonic::CM);
   Serial .print (distanceCM);
   Serial .println (" cm");

  if  (distanceCM  >  8){

  //Motor A forward @ full speed
   digitalWrite (12 , LOW);  //Establishes backward direction of Channel A
   digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
   analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
   //Motor B forward @ full speed
   digitalWrite (13 , HIGH); //Establishes forward direction of Channel B
   digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
   analogWrite (11 , 123);   //Spins the motor on Channel B at half speed

  }
if  (distanceCM <=  5){
   //Motor A backward @ full speed
   digitalWrite (12 , HIGH);  //Establishes forward direction of Channel A
   digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
   analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
   //Motor B backward @ full speed
   digitalWrite (13 , LOW); //Establishes backward direction of Channel B
   digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
   analogWrite (11 , 255);   //Spins the motor on Channel B at full speed
    }
  }
```

Our final design is a robot with tree ultrasonic sensors in front. One is looking forward and the other are 45º to the left or the right. The decision about the way is to choose the sensor with more distance. Here is a simple example of our robot avoiding obstacles:

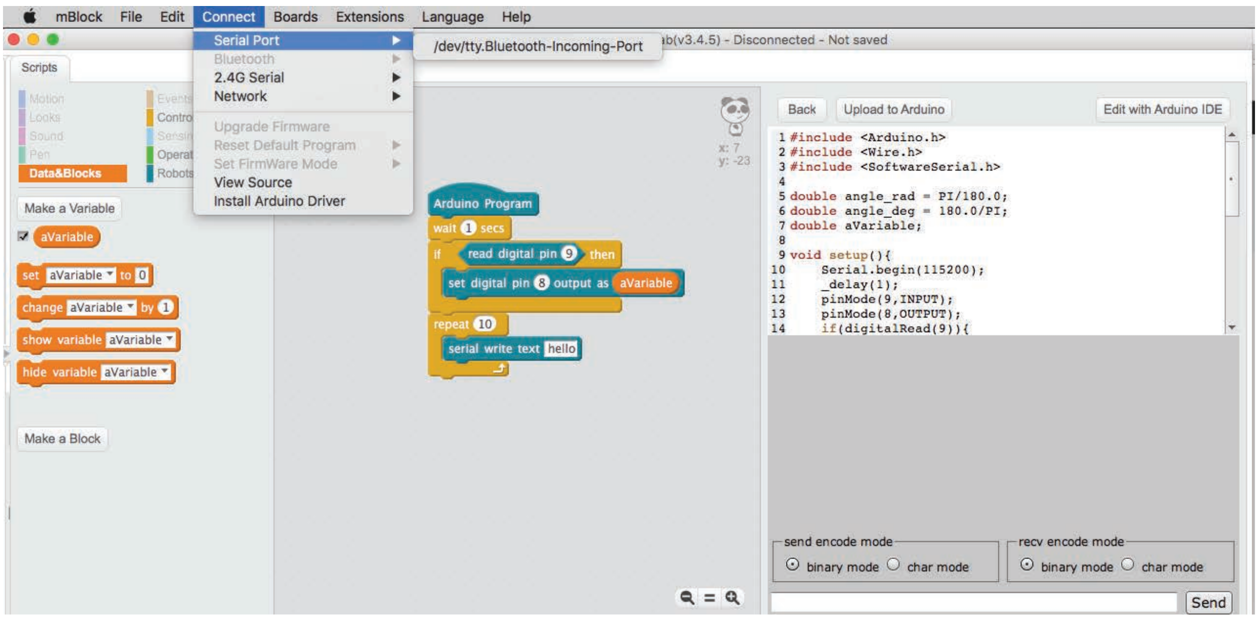
```
#include "Ultrasonic.h"
Ultrasonic ultrafront (7,6);
Ultrasonic ultraleft (5,4);
Ultrasonic ultraright (2,1);
long microsec  = 0;
float distanceCM  = 0;

void setup() {
//Setup Channel A
   pinMode (12 , OUTPUT); //Initiates Motor Channel A pin
   pinMode ( 9 , OUTPUT); //Initiates Brake Channel A pin
//Setup Channel B
   pinMode (13 , OUTPUT); //Initiates Motor Channel A pin
   pinMode ( 8 , OUTPUT);  //Initiates Brake Channel A pin
 }
void loop() {
   microsecfront  = ultrafront .timing(); // reading the sensor
   microsecleft  = ultraleft .timing(); // reading the sensor
   microsecright  = ultraright .timing(); // reading the sensor

  //convert the distance to cm
   distanceCMfront  = ultrafront .convert (microsecfront ,Ultrasonic::CM);
   distanceCMleft  = ultraleft .convert (microsecleft ,Ultrasonic::CM);
   distanceCMright  = ultraright .convert (microsecright ,Ultrasonic::CM);

  if (distanceCMfront > distanceCMleft && distanceCMfront > distanceCMright){
       //Motor A forward @ full speed
   digitalWrite (12 , LOW);  //Establishes backward direction of Channel A
   digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
   analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
      //Motor B forward @ full speed
   digitalWrite (13 , HIGH); //Establishes forward direction of Channel B
   digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
   analogWrite (11 , 123);   //Spins the motor on Channel B at half speed
   }
   if (distanceCMleft > distanceCMfront && distanceCMleft > distanceCMright){
      //Motor A backward @ full speed
   digitalWrite (12 , HIGH);  //Establishes forward direction of Channel A
   digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
   analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
      //Motor B forward @ full speed
   digitalWrite (13 , HIGH); //Establishes forward direction of Channel B
   digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
   analogWrite (11 , 123);   //Spins the motor on Channel B at half speed
   }

  if (distanceCMright > distanceCMleft && distanceCMright > distanceCMfront){
       //Motor A forward @ full speed
   digitalWrite (12 , LOW);  //Establishes backward direction of Channel A
   digitalWrite ( 9 , LOW);   //Disengage the Brake for Channel A
   analogWrite ( 3 , 123); //Spins the motor on Channel A at half speed
      //Motor B backward @ full speed
   digitalWrite (13 , LOW); //Establishes backward direction of Channel B
   digitalWrite ( 8 , LOW);   //Disengage the Brake for Channel B
   analogWrite (11 , 255);   //Spins the motor on Channel B at full speed
  }
}
```



Last words

To summarize, we have several tips to give:

- Remember that not all tutorials use the same hardware. For example, almost all tutorials for robots use the Adafruit motor shell. Many of them use an obsolete version of this. You have to adapt the code to your hardware.
- Many users have made their own library for sensors or other things. You can use it, but we recommend to use the more 'official' libraries you can find.
- The last examples we have written in this tutorial are intentionally made with different libraries or hardware to force you to read and test all the code you can find.
- Motors speeds, delays, servo angles or sensors calibration are specific for the hardware you have.
- Arduino is not only for robots. We recommend to explore other projects like art installations, domotics or industrial automation.



EFFECTIVE USE OF ROBOTS AND TRANSNATIONAL COOPERATION TO PROMOTE THE ESTEAM KNOWLEDGE

STAFF In this erasmus + ˝robots boosts skills˝ can attend STEM field professors, as well as students who are closely related to STEM areas.

Of course students are expected to have an interest in robotics to participate in this project. It is desirable for students to have the roots of robots they have gained in school or some outside teaching activities.

The professors will upgrade their existing knowledge of robots and robots with this project.

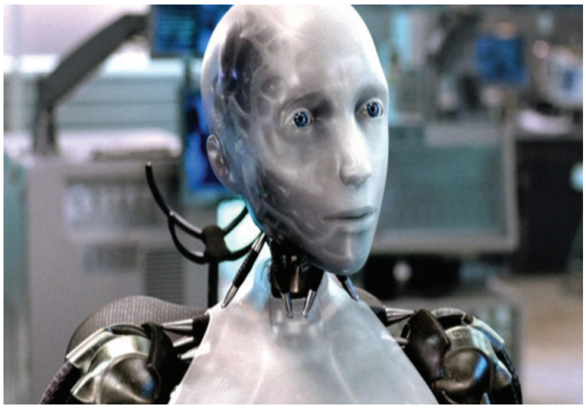
Icebreaking Activity

Robots are generally associated with science fiction and the future. As an opening of this international training, the following icebreaker activity can be used to get to know your participants to meet each other and recall some "famous" robot from the movies.

Procedure:

Participants will be divided into several groups. Each group will get photos, and for each photo will have to know the name of the movie and the name of at least one actor who plays in the movie.

STARWARS:THEFORCEAWAKEN(Harrison Ford, Carrie Fisher)



I ROBOT (Will Smith)

TERMINATOR (Arnold Schwarzenegger)

PUBLICITY / DISSEMINATION

Showcasing the work and activities in project is done by publicity and dissemination of results. The term "dissemination" is part of teachers vocabulary but in many cases without a real grasp of its meaning. We could classify it in three different ways:

1. Dissemination for Awareness – as a first step is best to reach as many people as possible to be aware of the project. That can be achieve with social media, word of mouth, newsletters etc. Creating such an awareness will help in building an identity and profile within community. Its imported to create an identity of project that will speak to audience and involve community.

2. Dissemination for Understanding – second step is to target specific groups with more detailed project work, where main focus is what it has to offer them. This will only be achievable and successful if, entire team has a shared vision and common understanding of what to disseminate together and a way of describing it to those that are outside of project and who may stand to benefit from work and results.

3. Dissemination for Action – third step is to have people who will react with the community and have change of practice from the adoption of products, materials or approaches offered by your project. Its best to have realistic goals and focus on quality of dissemination not quantity. The greater the involvement of audiences / community, the greater impact will be achieved and the stronger the routes of communication will be developed.

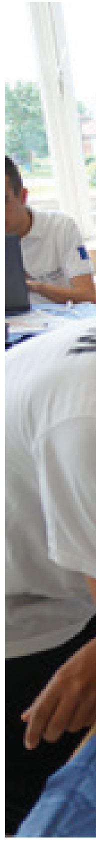
Every project is different therefore it needs its own kind of dissemination activities to achieve determent goals. Dissemination activities must be integral and vital part of project plan. The extent of dissemination and publicity can be increase with the size and strategic importance of the project with time.

Efficient and effective dissemination can be defined as that which engages the recipient in a process whether it is one of increased awareness, understanding or commitment and action. The planning and development of dissemination strategy must have equal importance placed on it as the other preparatory work. It is important to consider each target audience / group and the level of dissemination required at every stage of project and begin to plan the timing.

The following list is an idea of different types of dissemination media that area available to use:

• social media (Facebook, Instagram, SnapChat etc.) – a way to promote and publicise project activities in project to new generations,

• mailing lists – a way to receive materials and information about project to key people,



• workshops – targets smaller groups of participants and involves a much higher and more active level of engagement,

• websites - allows easy access to information about project activities and is easily updated,

• newsletters – a way that keeps audience / community informed of progress and continue to stimulate interest,

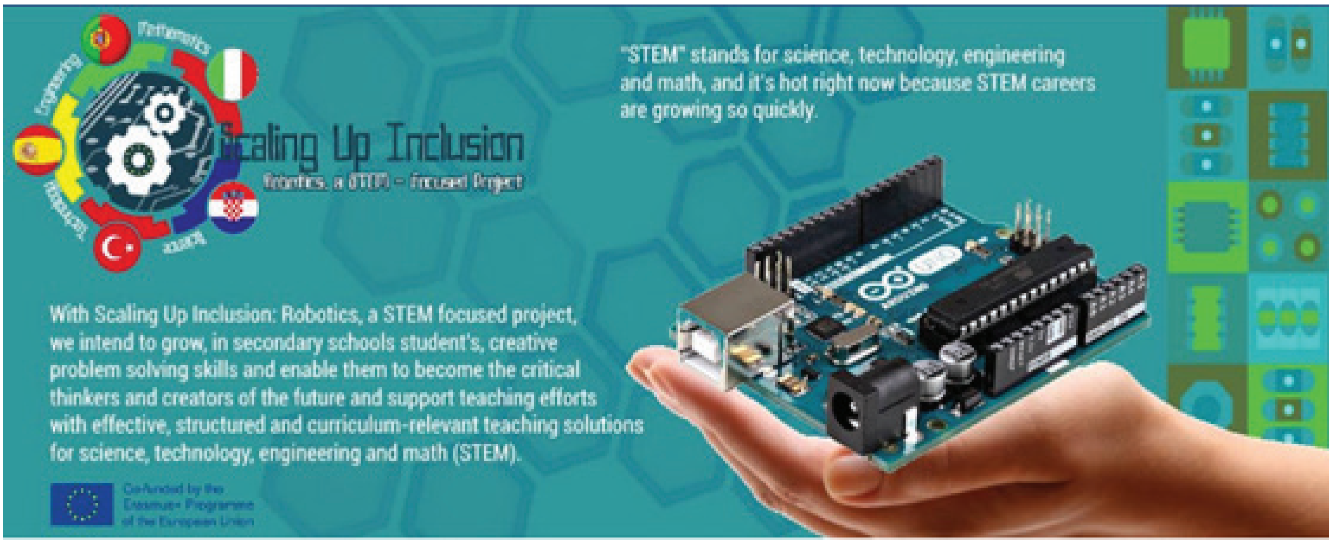
• briefings - can be partway between a newsletter and a catalogue,

• conferences - can be a very useful forum to consult with target audiences in a face-to-face capacity and to address issues relevant to the work of project in hand,

• media - can increase the profile of project activities and results greatly and reach a very wide body of people.

Example:

https://www.facebook.com/scalingupinclusion



AWARDS/CERTIFICATES

An essential 21st century skill is being able to collaborate. No matter what awards system we use, it important to promote individuals as opposed to the efforts of working together. With creative, safe and caring environment all students will learn and improve, not just the ones that are strong at the core subjects. Those are the pre settings for a successful project where students will learn new skills as a best kind of award.

Appreciation certificates are special documents that are designed by institutions or individuals to show and display appreciation for support or work that students and teachers have done. Various organisations or institutions may have different certificate of appreciation template. Regardless appreciation can either be used at the end or certain intervals of the project, as achievement of the desired goal.

Certificates issued in between a certain project are designed to boost the morale of the individual or group of students as they continue with the project at hand. Research has revealed that appreciation certificates reinforce desired performance behaviours among people and this boosts their self-image and make them feel like winners.

Verbal recognition may be closely related to awards and certificates, but it cannot supersede the accrued benefits that go alongside awards and certificates. Leaders or teachers should embrace this method to reinforce and improve efficient work performance among students.

Appreciating achievements of students helps improve their performance in coming days. Certificates have different contents that include:

• name of the person,

• the reason for presenting the certificate,

• statement of appreciation,

• name of the organisation / institute issuing the certificate,

• name of the authorized person issuing the certificate.

Co-funded by the Erasmus+ Programme of the European Union

Certificate of Attendance

This is to certify that

(name of the participant.........)

Attended the Short-term joint staff training event of the project

ROBOTS - RObots BOosts Skills

Nº: 2017-1-ES01-KA202-038277

held in ********

from ...... to .... December 2017

organised by

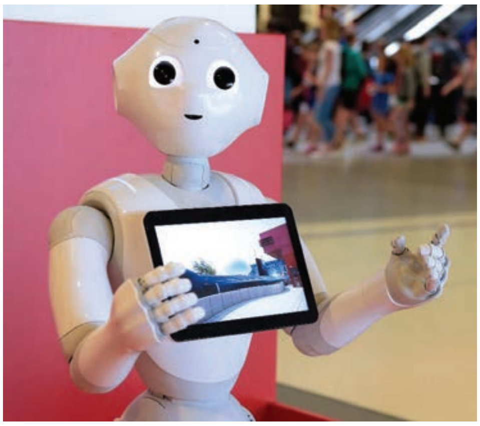
IES ************

Director

****

SUCCESSFUL COOPERATION

The project contributes to the priority "Further stengthening key competences in VET" through more effective, innovative teaching methods. Robots it's an innovative an effective way to motivate students to ESTEAM areas. Robots will allow students apply real-world Math, Engineering, Technology, Art and Science concepts and to develop strategic problem solving, critical thinking, organizational, teamwork skills, collaboration and communication while becoming more self-confident enhacing pupils' motivation to learn and to stay at school through programming ROBOTS as teaching and learning tool for promoting



students interest in ESTEAM and active participation to school activities.

The project will contribute also to the second priority "Open and innovative practices in the digital era" because Robots will help the students to a better comprehension and knowledge of the most innovative and technical solutions available to be used for developing educational contents.

The rapid digital transformation of the economy means that almost all jobs now require some level of digital skills, as does participation in society at large. The collaborative economy is changing business models and is demanding different skill sets, and bringing challenges such as access in upskilling opportunities. Robotisation and artificial intelligence are replacing routine jobs, not only on the enterprises but in normal live. Access to services, ,is changing and requires that both users and providers be more and more skilled on ICT.

I-VET Teachers could enhance I-VET students' motivation to learn and to stay at school through programming ROBOTS as teaching and learning tool for promoting I-VET students interest in ESTEAM (Equality, Science, Tecnhology, engineering, art and math).

The project partners think that using ROBOTS supports modern learning theories. Using robots I-VET students participate and experiment in secure virtual environments (Activity Theory), learners experience different situations (Situated Learning), and learners learn through direct experiences based on their interactions with the robot.

And the project will contribute to "social inclusion" because during the project activities parters will use formal and non-formal and informal education and training programming robots, developing intercultural competences, combating discrimination and segregation and reducing disparities. Project partners will work with students with disadvantaged backgrounds using robots as an innovative approach. The project also will promote the participation and performance of disadvantaged learners.

Robot learning is a research field at the intersection of machine learning and robotics