Key Action: KA2: Cooperation for Innovation and the Exchange of Good Practices, KA201 - Strategic Partnerships for school education
Project name: STEAM education and learning by Robotics, 3D and Mobile technologies - FabLab SchoolNet
Project No.: 2018-1-LT01-KA201-047064

INTELLECTUAL OUTPUT 1 - LEARNING MODEL FOR TEACHING WITH LEARNING BY MAKING APPROACH

Output Type: Methodologies / Guidelines – Methodological framework for implementation	
Activity Leading Organisation	Universitatea „Dunarea de Jos" din Galati
Participating Organisations	Siauliu Didzdvario gimnazija CONSIGLIO NAZIONALE DELLE RICERCHE 2 EPAL TRIKALON Varnenska morska gimnazia "Sv. Nikolai Chudotvorec" FabLab Palermo APS

Due Submission Date:	28/01/2019
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Project Number	2018-1-LT01-KA201-047064
Instrument:	Strategic Partnerships for school education
Start/Finish Date of Project:	01.11.2018 – 31.10.2020
Duration:	24 months

Abstract
This Intellectual Output will define a methodological approach for teaching with innovative technologies with particular focus on school contexts. The advantages of using a learning by making approach will be investigated. Subsequently, the methodological approach will be described in order to be tested by teachers with students. In this intellectual output, guidelines to support teachers in undertaking learning path based on the technologies of FabLab Schoolnet will be drawn up. Specifically, a teaching methodology will be defined with the aim of: - helping teachers in identifying the most relevant activities that can be implemented with the use of mobile, robotics and 3D technologies, to stimulate students creativity; - being helpful for teachers in the process of teaching; - guiding teachers in supporting learners during all learning phases. Moreover, the most appropriate tools to be used to support the methodological approach wil be also identified in this output.
Output Type: Methodologies / Guidelines – Methodological framework for implementation
After a relevant analysis undertaken by involved partners, a learning model for teaching with FabLab Schoolnet technologies will be developed. All partners will participate in the technical committee to draw up a list of priorities that will define the basis of the methodological approach. Providing the point of view of schools and technology enables (FabLab Palermo, CNR, UDJG). The methodological approach for teaching with innovative technologies will be developed, according to the decisions defined by the technical committee. The model produced will be tested directly with students and teachers by the schools involved in the project. At the end of the test the results will be published and further changes to the model will be applied, in order to enhance its efficacy. Moreover, the results of the testing of the model will be used to highlight anomalies and critical points in order to improve the model before publishing and conducting a testing on a large scale.

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FabLab SchoolNet

Module 1.
STEAM education. A powerful approach for modern education

Is education prepared for the new generation of children?

Lassic work-classes .....

Young generation .. is evolving

Millennials / Generation Y / Net Generation
Dynamic, creative, born in informational era

Old generation children…

Ethical, with Moral Values, Statical,

STEM

Science

Technology

Engineering

Math

STEM 1.0

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History of STEM and STEAM

There is no universal definition of STEM, however experts generally agree that STEM workers use their knowledge of science, technology, engineering, or math to try to understand how the world works and to solve problems.”

Occupational Outlook Quarterly • Spring 2014

STEM

- Originally SMET. Acronym STEM is “stickier”
- “An educational inquiry process where learning was placed in a context, where students solved real-life problems and created opportunities → the pursuit of innovation”

Dr. Judith Ramaley, Assistant Director of the Edcuation and Human Resources National Science Foundation

STEAM

- John Maeda – Rhode Island School of Design – urged the insertion of Arts.
- Role of creative problem-solving and aesthetic in creating innovative solutions
- Form informs function. Function informs form

What are the favorite aspects of STEAM?

- ❖Addresses real world problems
- ❖Focus on inquiry as a iterative process
- ❖Meet standards of cross-curricular disciplines
- ❖Students collaboratively construct projects
- ❖Builds students' agency about their learning

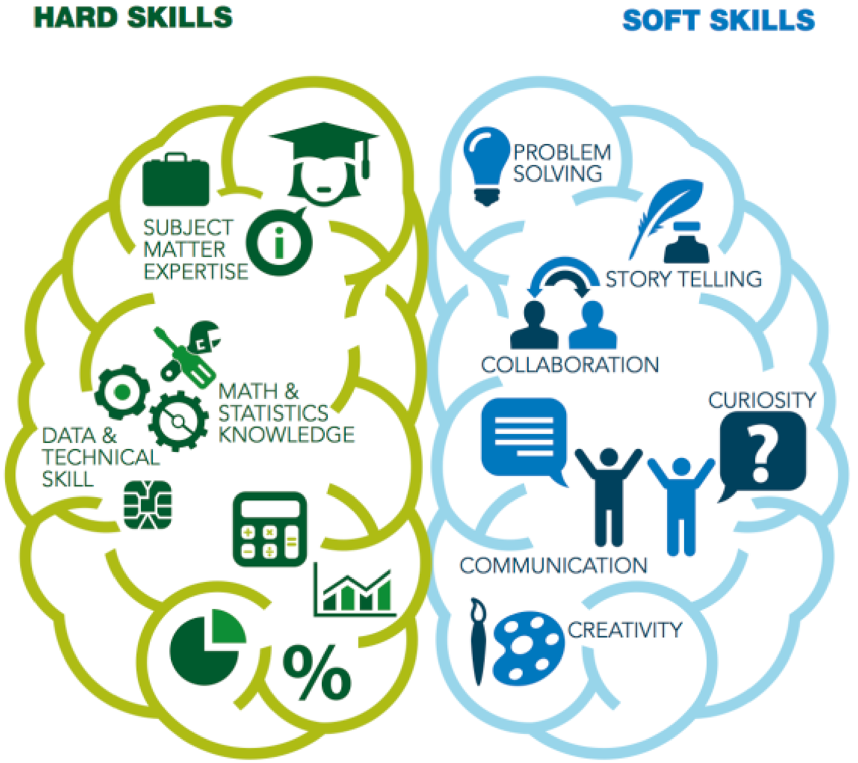
- ❖POOL

- ❖Which of these aspects of STEAM are most reasonable for you?

Not a Lesson or Curriculum..
An approach to Teaching and Learning

- Teachers as co-learners and facilitators
- Collaboration between specialist and classroom teachers
- Student-centered mindset in planning and implementation
- Highly exploratory, inquiry based units (bigger than lesson)
- Teacher-talk is a minimum. Student interaction drive discovery
- Authentic assessment, based on process and artifacts, not textbooks/tests.

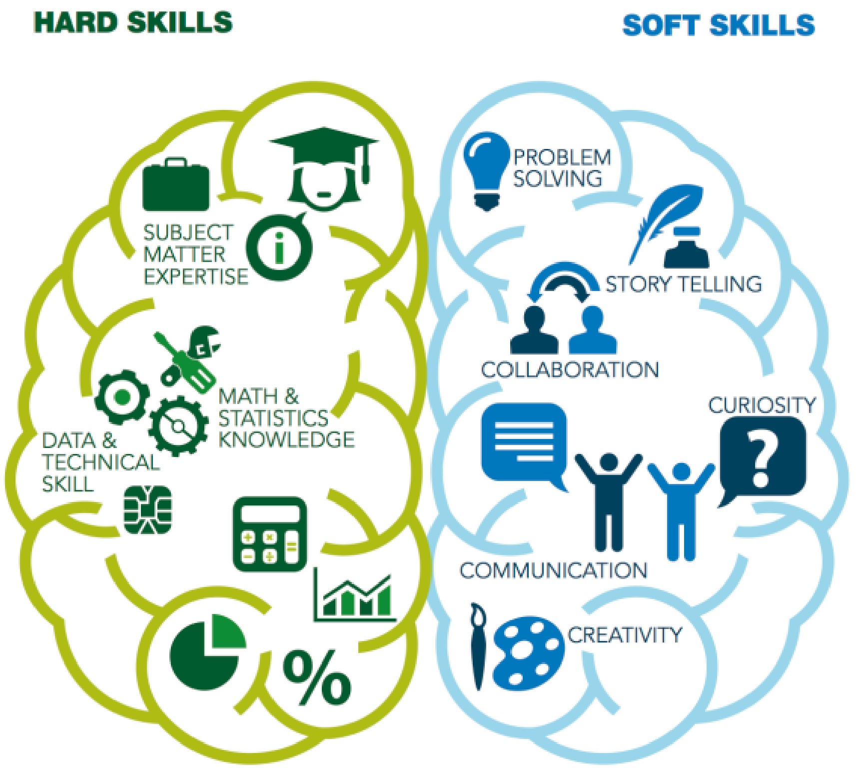
STEM Skills



- **Analytical skills** to research a topic, develop a project and timeline, and draw conclusions from research results.
- **Science skills** to break down a complex scientific system into smaller parts, recognize cause and effect relationships, and defend opinions using facts.
- **Mathematic skills** for calculations and measurements.
- **Attention to detail** by following technical directions, recording data accurately, formative and summative assessment.

STEM Skills

- **Technical skills**, troubleshooting, repairing, and utilizing software an modern equipment.
- **Communication and cooperation skills** to listen to customer needs interact with project partners.
- **Teamwork skills** for successful project completion.
- **Creativity** to solve problems and develop new ideas.
- **Leadership skills** to lead projects or help customers.
- **Organization skills** to keep track of lots of different information.
- **Time management skills** to function efficiently.



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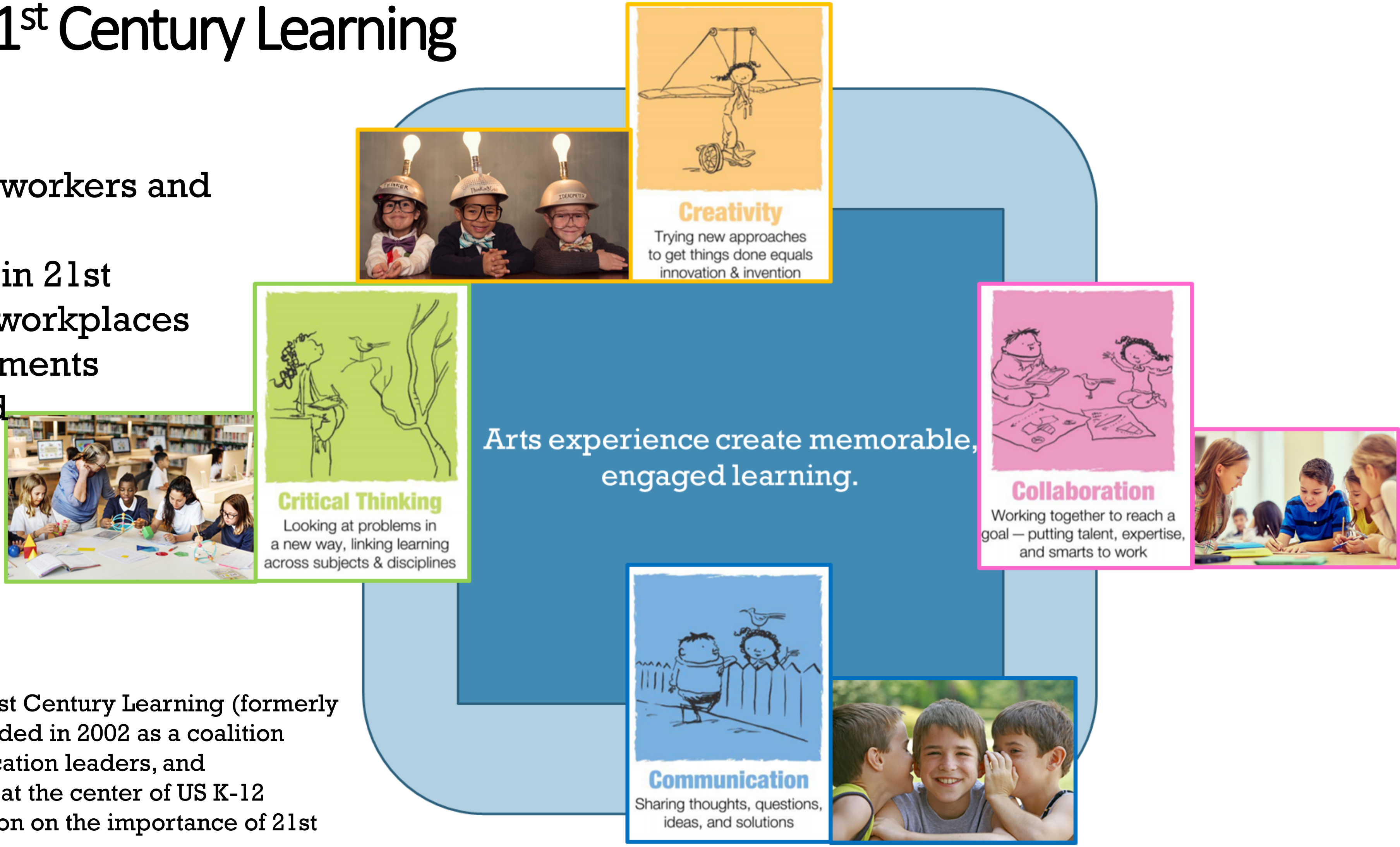
P21 Partnership for 21st Century Learning

- Become effective citizens, workers and leaders.
- Learn what they need to join 21st century communities and workplaces
- Thrive in learning environments aligned with the real world



About the Institution: P21, The Partnership for 21st Century Learning (formerly the Partnership for 21st Century Skills) was founded in 2002 as a coalition bringing together the business community, education leaders, and policymakers to position 21st century readiness at the center of US K-12 education and to kick-start a national conversation on the importance of 21st century skills for all students.

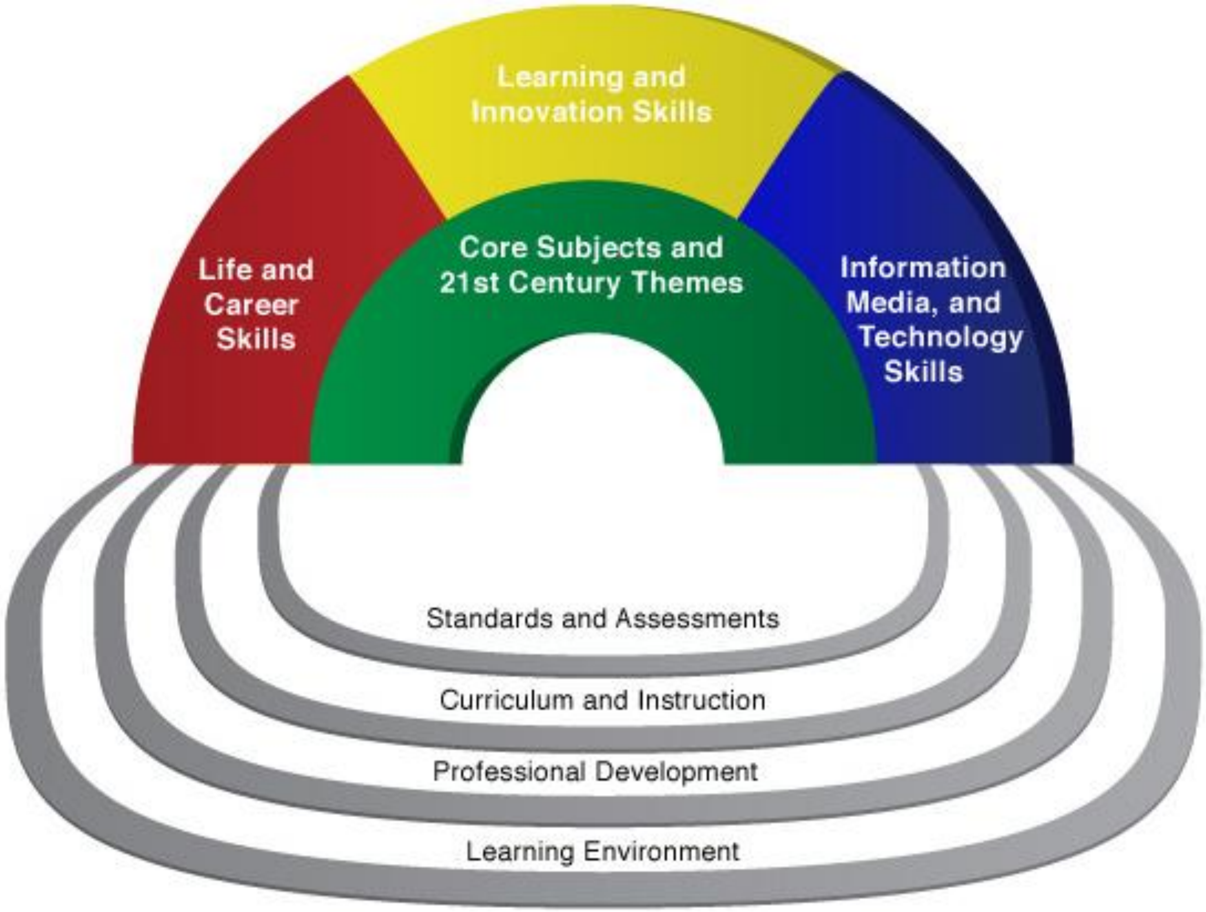
Partners

Adobe
AASL American Association of School Librarians
AP
cable in the classroom Kids. Cable. Learning.
CENGAGE Learning
CISCO
Crayola
DELL
EdLeader21
EF Education
ena Education Networks of America
Ford Motor Company Fund and Community Services
GlobalScholar Empowering the world to learn
The Goddard School for Early Childhood Development
hp
Houghton Mifflin Harcourt
intel
KnowledgeWorks
KNOVATION Making learning personal.
LEGO
Mosaica Education, Inc.
National Academy Foundation
nea National Education Association nea.org Great Public Schools for Every Student
PMI Project Management Institute Educational Foundation
PEARSON
VIF International Education
The Walt Disney Company
wireless generation
verizon
Partnership for 21st Century Skills

Funded by the Erasmus+ Programme of the European Union

21st Century Skills

- **Life and career skills**
- **Learning and innovation skills**
  - Creativity and innovation
  - Critical thinking and problem solving
  - Communication and collaboration
- **Information, media, and technology skills**
- **Core subjects and 21st Century & Themes**
  - English, reading or language arts
  - World languages
  - Arts
  - Mathematics
  - Economics
  - Science
  - Geography
  - History
  - Government and Civics



4Cs
(Critical Thinking, Communication, Collaboration, and Creativity)

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STEM can be…

1. **Interdisciplinary –** formal, physical, life, social & applied science
2. **Curriculum** driven by problem-solving, discovery, exploratory learning, active learning to find solutions
3. **“A meta-discipline”** transforming subject matter by incorporating technology & engineering

STEM. Evolution

STEM 2.0	STEM 3.0	STEM 4.0
STEM disciplines	**STEM disciplines**	**STEM disciplines**
Science and Tehnology	Science, Tehnology and Engineering	Science, Tehnology, Engineering and Math
Science and Engineering	Science, Engineering and Math	↑
Science and Math	Tehnology, Engineering and Math	**Integration**
Tehnology and Engineering	Math, Tehnology and Science	
Tehnology and Math		
Engineering and Math		

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S is for Science

- Children are natural scientists. They try to figure out just how the world works by engaging in a series of steps called the scientific method. The scientific method includes observing, forming questions, making predictions, designing and carrying out experiments, and discussing. Even infants and toddlers are using a basic form of the scientific method (or performing little experiments) as they explore and discover the world around them!

- Children find patterns and build theories to explain what they see, and collect "data" to test those theories. A theory is like a guess or possible explanation for something. A toddler makes footprints after she walks through a puddle. She may form a theory based on her observation of her footprints, that the way she walks changes the size and shape of the prints. She then tests her theory by hopping on one foot or walking on her toes to see if her prints change.

- Like scientists, children learn from others. They watch what children and adults do and learn from trying to repeat what they've seen or by asking questions and seeing the results.

T is for Technology

- When we think of technology, cell phones and computers often come to mind. But the "T" in technology also stands for any type of man-made object. Technology includes simple tools such as pulleys, wheels, levers, scissors, and ramps. They support children's cognitive development, because as children play with these tools, they observe and learn from the underlying cause and effect.
- These simpler technologies allow children to understand how tools help us accomplish tasks. Children can see the cause and effect behind them, like how adding wheels below a large object makes it easier to move, or how raising a ramp makes a ball roll faster.

What is STEAM?

S is for Science

T is for Technology

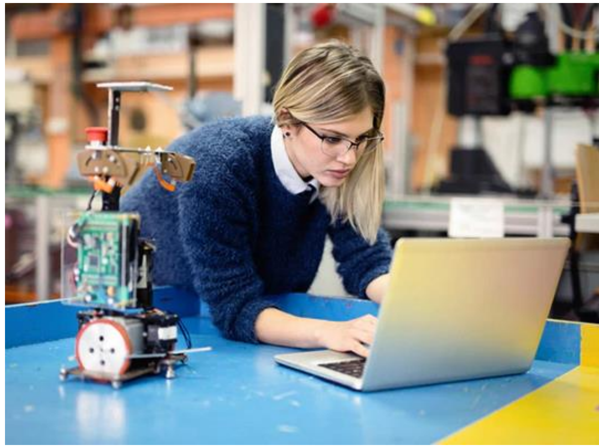
E is for Engineering

A is for Arts

M is for Math

E is for Engineering

- Engineering applies science, math, and technology to solving problems. Engineering is using materials, designing, crafting, and building – it helps us understand how and why things work.
- When children design and build with blocks or put together railroad tracks, they are acting as engineers. When children construct a fort of snow, pillows, or cardboard, they are solving structural problems.
- When they figure out how to pile sticks and rocks to block a stream of water or how objects fit together, they are engineering.



A is for Arts

- A creative mindset is critical for STEM subjects. That is why the arts was added to STEM to become STEAM. Scientists, technology developers, engineers, and mathematicians need to innovate and solve problems creatively. The subjects in STEAM are similar in their approach to learning.

- Active and self-guided discovery is core to the arts and to STEAM learning. Children engage in painting, pretend play, music, and drawing. Art is sensory exploration. Children can feel the paint on their fingers and see colors change the way paper looks. As they grow, children include symbols in their art that represent real objects, events, and feelings. Drawing and play-acting allow them to express what they know and feel, even before they can read or write. Music is also linked to STEAM skills such as pattern recognition and numeration.

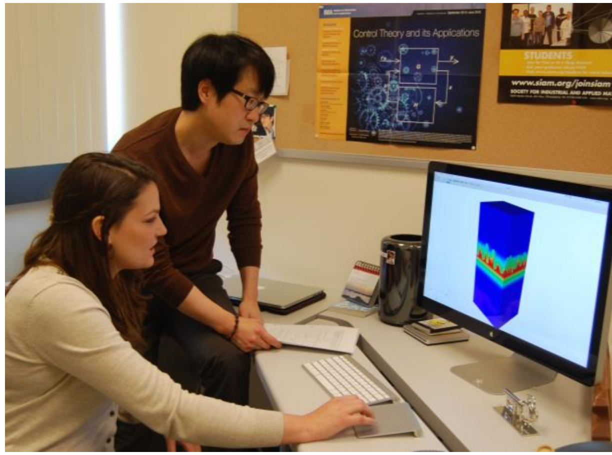
- Research shows that early experience with creative arts supports cognitive development and increases self-esteem.

What is STEAM?

- S is for Science
- T is for Technology
- E is for Engineering
- A is for Arts
- M is for Math

M is for Mathematics

- Math is number and operations, measurement, patterns, geometry and spatial sense. From birth until age five, children explore everyday mathematics, including informal knowledge of "more" and "less," shape, size, sequencing, volume, and distance. Math is a tool children use every day!
- Babies and toddlers learn early math concepts like geometry and spatial relationships when they explore new objects with their hands and mouths. Teaching staff support math learning with infants and toddlers by intentionally using math language throughout the day.
- They make math concepts visible when they connect them to objects and actions. Infants begin to understand the math concept "more" early on and often use it to signal they want more food or drink.



Everyday language that supports STEAM thinking

Observe
- What do you see?
- What do you hear?
- How do they sound and smell?
- How are they the same?
- How are they different?
- What happens when you try?
- You seem curious about...

Question
- What are you curious about?
- What do you want to know?
- Are you wondering if…?

Predict
- What do you think will happen?
- What are your predictions?
- Why do you think that?
- How could we find out?

Explore/ Experiment
- Let's investigate.
- What do you notice?
- What is changing?
- What did you try?
- Let's draw what we see.

Discuss
- What were your predictions?
- What happened?
- What did you notice?
- Why do you think that happened?
- What could we investigate next?


Part of the MIT - Nord Anglia STEAM collboration
What is STEAM?
NORD ANGLIA EDUCATION

Integrated Learning

High demand for **integrated learning**.

- Integrated learning has gained renewed strength in education with the growth of STEM, among other progressive learning models.

- STEM not only provides more hands-on application, but it better prepares students to analyze and learn critical thinking skills that will be valuable to their future education and professional pursuits — both inside and outside the STEM fields.

A 21st century workforce that requires 21st century skills

- As more educators recognize the importance of interdisciplinary curriculum, fewer students will participate in siloed subjects as they learn how to apply problem-solving skills.
- As a result, those students will be more prepared for 21st century learning and professional life, and will also gain a greater motivation to learn.
- For example, in an integrated physics and chemistry (IPC) curriculum, the class would focus on understanding each discipline and how it correlates with the other.
- Students would gain a deeper understanding of how the principles of both could be applied in the real world.

The need for real-world application experience…in school.

- Integrated studies give students the opportunity to use both modern technology and social engagement to increase their understanding.
- It also requires more hands-on learning and real-word application. All of this helps prepare students for further education and careers.
- By learning within a curriculum that uses real-world applications, students develop a better grasp of the material as they see how the topics relate to scenarios outside of the classroom.

The STEAM movement is gathering momentum.

- Much attention in education is being paid to integrating arts and language arts into the STEM conversation (i.e., STEAM).
- Before we can focus on this shift, however, we need to make sure the STEM subjects themselves are more cross-curricular in nature.
- The sciences, for instance, are often extremely siloed in traditional curricula.
- By "connecting the "dots" of science, chemistry, physics, and other subjects when teaching concepts, we can make the learning experience more authentic and relevant.
- This, in turn, allows students to make more connections…because they didn't learn the subjects in isolation.

A move away from single-topic lesson plans.

- The conversion to de-siloed learning in the STEM disciplines will take time, but can be accomplished at a steady pace through small changes in school curriculum.
- De-siloed STEM learning can move teachers away from single-topic lesson plans and enable them to give students exposure to more sophisticated, integrated approaches to learning.
- A lesson on the human body for example, can incorporate chemical reactions, force, and other real-world concepts.

The need to replace antiquated learning materials.

- Many states are still using textbooks that were published prior to standards revisions. In some cases, these were published prior to multiple revisions, and are no longer aligned to the majority of state standards. Using a decade-old textbook leaves teachers extremely frustrated, namely because the new standards are much more rigorous and detailed.

- One particularly useful resource that makes it easy for teachers to deliver lessons that cross the STEM subjects is a digital, inquiry-based K-12 curriculum called STEM scopes.

- Developed in partnership by Rice University and Accelerate Learning, STEM scopes was built from the ground up to meet state standards and the NGSS. Its student-centric, blended STEM learning environment helps students master standards through scientific investigations, engineering challenges, content connection videos, claim-evidence-reasoning assessments, and more.

A rise in student-centric technology platforms

- A key benefit of digital curriculum materials is that they allow the teacher to personalize lessons for their students and address the content in a creative way.
- By combining digital resources, supplemental print, and hands-on kits, STEM scopes K-12, for example, adapt to any teaching style while increasing engagement, rigor, and student achievement.
- Whether the style is traditional, blended or 1:1, the platform offers a variety of opportunities for integrated and hands-on learning.
- There is even a Spanish version for grades K-5, which further allows the teacher to meet the needs of their students. This goes a long way in breaking down the educational silos that are holding our students and teachers back.

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5 Miths about STEAM Learning

"We don't really have any budget for all those flashy robots!"

STEAM is about integrated problem solving and can be completely 'unplugged!'

- common complaint is how expensive the STEAM equipment are
- the danger is that teachers disregard the learning pedagogy that STEAM relies on
- the best way to get the most out of STEAM is to have students collaborating and seeking to solve real-world, authentic problems.

- focus on the pedagogy first, and then experience and unpack that understanding with very 'low tech' challenges
- involve cheap materials
- work through the Design Thinking Process, and do it over and over again until you succeed
- STEAM challenge in the end

5 Miths about STEAM Learning

"You need a dedicated room, don't you?"

STEAM reaches its potential for impact when embedded in all classrooms.

- too many schools spending large amount of money on dedicated rooms
- The room are to create, setup and store STEAM projects.
- The danger with these 'maker spaces' is that they risk becoming the latest version of the 1990's computer lab → majority of teachers avoid integrating STEAM

- STEAM can be done in any room, with any tools and in any environment
- There are some spaces that make it easier or more manageable, but this is not absolutely necessary and can easily be more detrimental to widespread school STEAM integration.

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5 Miths about STEAM Learning

> "The E isn't something we need to focus on at our level."
>
> Engineering is the intersection between 'Science' and 'Technology,' ie. 'making'.

- Engineering can easily be seen as something that students will explore when they reach tertiary level study, or get into the trades.

- However, in essence, engineering is a way to describe the designing and making aspect of a STEAM project. It can be seen as the intersection of our science understanding and what we know as technology. This is something a 5 year old will do when they are building with Lego or constructing a bridge out of newspaper.

- There are four forms of engineering:
  - Mechanical,
  - Electrical,
  - Chemical,
  - Civil.
- All of these disciplines have a body of knowledge that teachers can plan for and enable their students to explore and discover.
- Having this understanding as a teacher is why professional development and teacher experience is crucial to successful STEAM learning in your school.

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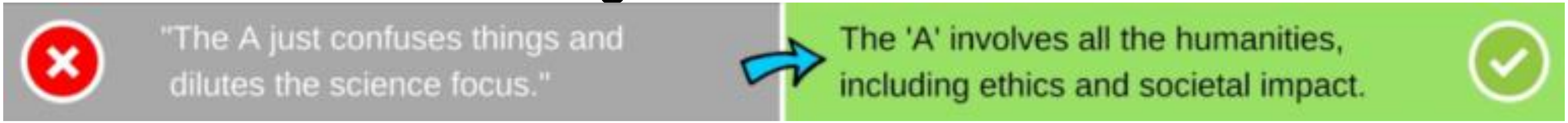
5 Miths about STEAM Learning



- Some principal's are well-meaning in wanting to focus on the Science and Technology development for their teachers, while Secondary teachers often like to focus on their speciality area of subject-based expertise.

- Both of these people will state that a focus on integrating the visual arts will dilute the emphasis on the STEM areas.

- However, in many minds, the 'A' includes far much more than the aesthetic or emotive features of a solution to a need or a want. If you unpack what the arts are, you realise that it includes all of the humanities subjects.

- Some would argue that the lack of consideration and thought into the 'A' in STEM is a growing concern for our modern society. I think that we disregard the 'A' to our peril.

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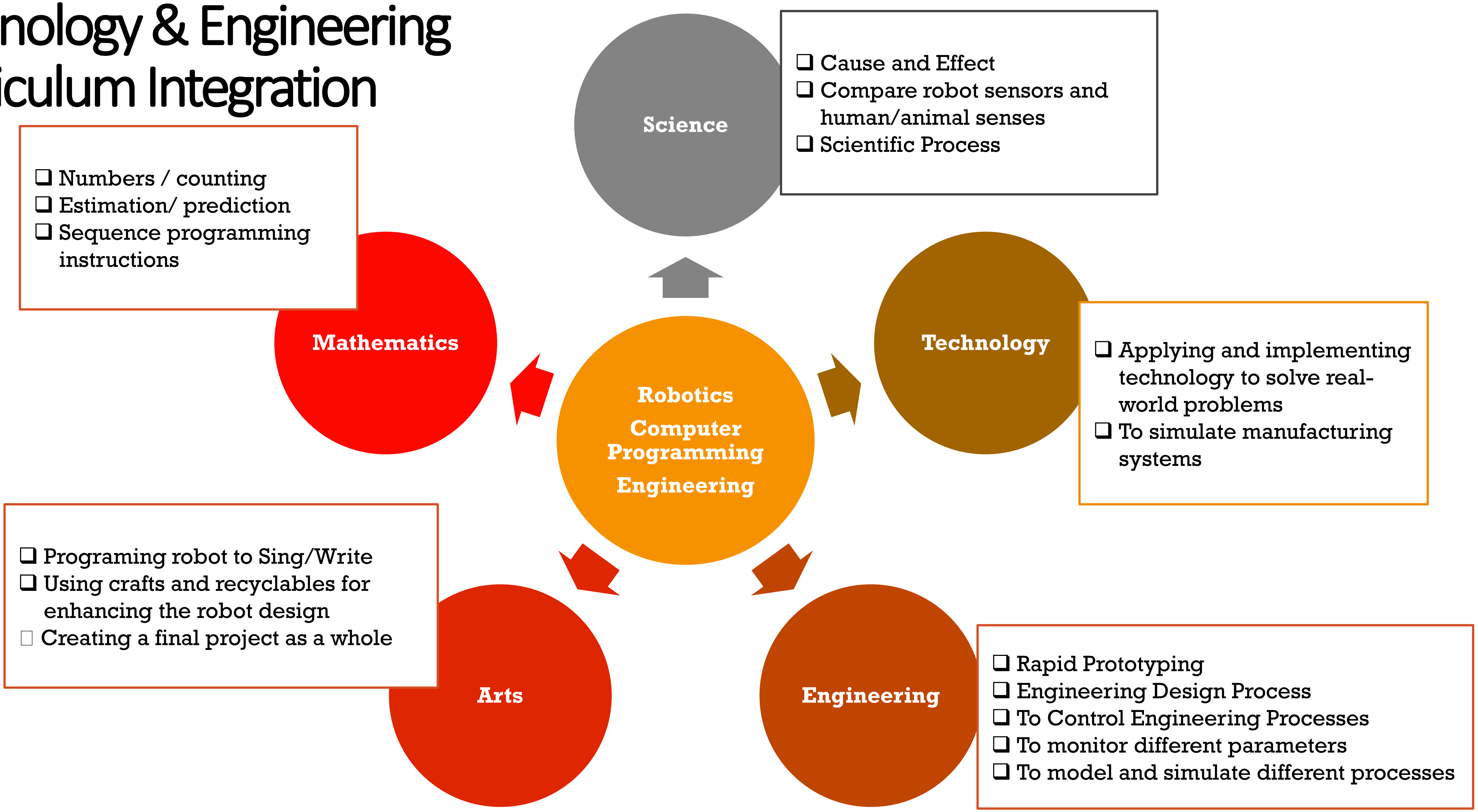
5 Miths about STEAM Learning

"Just give it to the students and let them 'go for it!'" → The teacher's role is to guide, scaffold, instruct and encourage - critical to success!

- Teachers and leaders are lacking the knowledge of a new tool or product themselves.
- The curious nature and 'give it a go' attitude of many younger learners will keep them engaged for a while.
- However, it's only a matter of time before that engagement will start to wain and boredom will kick in.
- For most students, this strategy only works for a limited amount of time before they get distracted or disinterested.

- The role of the teacher and their understanding of a tool's limitations and strengths is critical for getting the most from the STEAM learning approach. A teacher's goal should be to develop the 6Cs of;
  - creativity,
  - collaboration,
  - critical thinking,
  - global connections,
  - character,
  - citizenship.
- To do this effectively, students need a teacher's understanding of a tool to help them problem solve, be inspired, and have the possibilities modelled to them.

Technology & Engineering Curriculum Integration



STEAM Teaching and Learning Model

Launch
What can it look like?
- Share the Learning Intention and Success Criteria – displayed and referred to throughout the lesson.
- Explicit teaching of the skills and strategies as determined by formative assessment and/or cohort needs.
- Codevelop anchor charts are display in the learning space to support learning.
- Exposure to consistent vocabulary.

Independent / Collaborative Learning
What can it look like?
- The teacher facilitates and supports the learning process.
- Students independently or in small groups practise or apply the focus of the launch and/or their specific learning goals.
- Learning tasks and goals are differentiated and/or open ended to support learning needs.
- Students utilise a variety of resources within the classroom.
- Students learn the skills and then apply their knowledge to problem solving.

Reflection
What can it look like?
- Opportunity to self-assess against the Success Criteria and identify direction for future learning.
- Students articulate what they have learnt and the strategies/processes they used.
- Recognise and celebrate student learning.
- Reflection strategies vary from lesson to lesson e.g. partner, individual, thinking routines, exit pass etc.
- Discuss misconceptions observed during the session.

Launch (5-10 Minutes) → **Independent / Collaborative Learning (30 - 40 Minutes)** → **Reflection (5-10 Minutes)**

Formative Assessment and Feedback
Examples: teacher questioning, observation notes during turn and talk tasks, conferencing and goals setting records, anecdotal records, collecting work samples, photographing or filming students, checklists, rubrics, journal entries, exit strategies such as an exit pass, peer and self-assessment tools etc.

Givens
- Students engage in one STEAM lesson each week.
- The CNPS STEAM Curriculum includes at least one term of Digital and Design Technology and two terms of Visual Art and Media during the course of the school year.

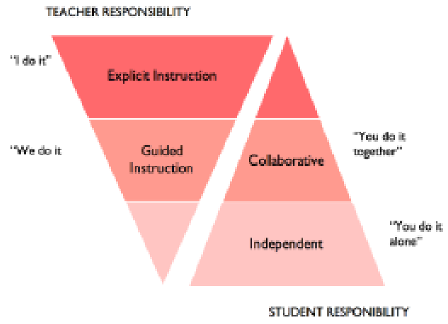
Science
Science Understanding
Science understanding is evident when a student selects and integrates appropriate Science knowledge to explain and predict phenomena, and applies that knowledge to new situations.

Science Inquiry Skills
- Questioning and Predicting
- Planning and Conducting
- Recording and Processing
- Analysing and Evaluating
- Communicating

Technology
Design and Technologies aims to develop the knowledge, understanding and skills to ensure that students:
- become critical users of technologies, and designers and producers of designed solutions.
- use design and systems thinking to generate innovative and ethical designs and communicate these to a range of audiences.
- create designed solutions for a range of contexts by creatively selecting and safely manipulating a range of materials, systems, components, tools and equipment.
- Learn how to transfer knowledge and skills from design and technologies to new situations.

Digital Technologies
The Design Technologies aims to ensure that students can:
- design create, manage and evaluate sustainable and innovative digital solutions to meet and redefine current and future needs.
- use computational thinking and the key concepts of abstraction; data collection, representation and interpretation; specification, algorithms and development to create digital solutions.
- confidently use digital systems to efficiently automate the transformation of data into information and to creatively communicate ideas in a range of settings.

Visual and Media Arts
The Visual Arts curriculum aims to develop students':
- conceptual and perceptual ideas and expression through design and inquiry processes.
- Visual and Media Arts techniques, materials, processes and technologies.
- critical and creative thinking, using visual arts languages, theories and practices to apply aesthetic judgement.
- confidence, curiosity, imagination and enjoyment and a personal aesthetic through engagement with visual arts, making, viewing, discussing, analysing, interpreting and evaluating.



At CNPS all staff acknowledge the importance of student voice and agency within their learning. Students are provided with opportunities to contribute to what they learn, how they learn and how they demonstrate their learning.

Conclusion

- Silo effect that has dominated education needs to be eliminated, so today's students can more effectively develop real-world skills .
- As more teachers focus on interdisciplinary studies, siloed classes may gradually become obsolete.
- This, in turn, will help cultivate an educational environment where even the most technical subjects can be broken down into digestible, understandable chunks and consumed by today's 21^{st} century learners.
- STEAM learning is an incredible new approach to making learning real for our students, in a way that enables them to be as 'future ready' as they can be.

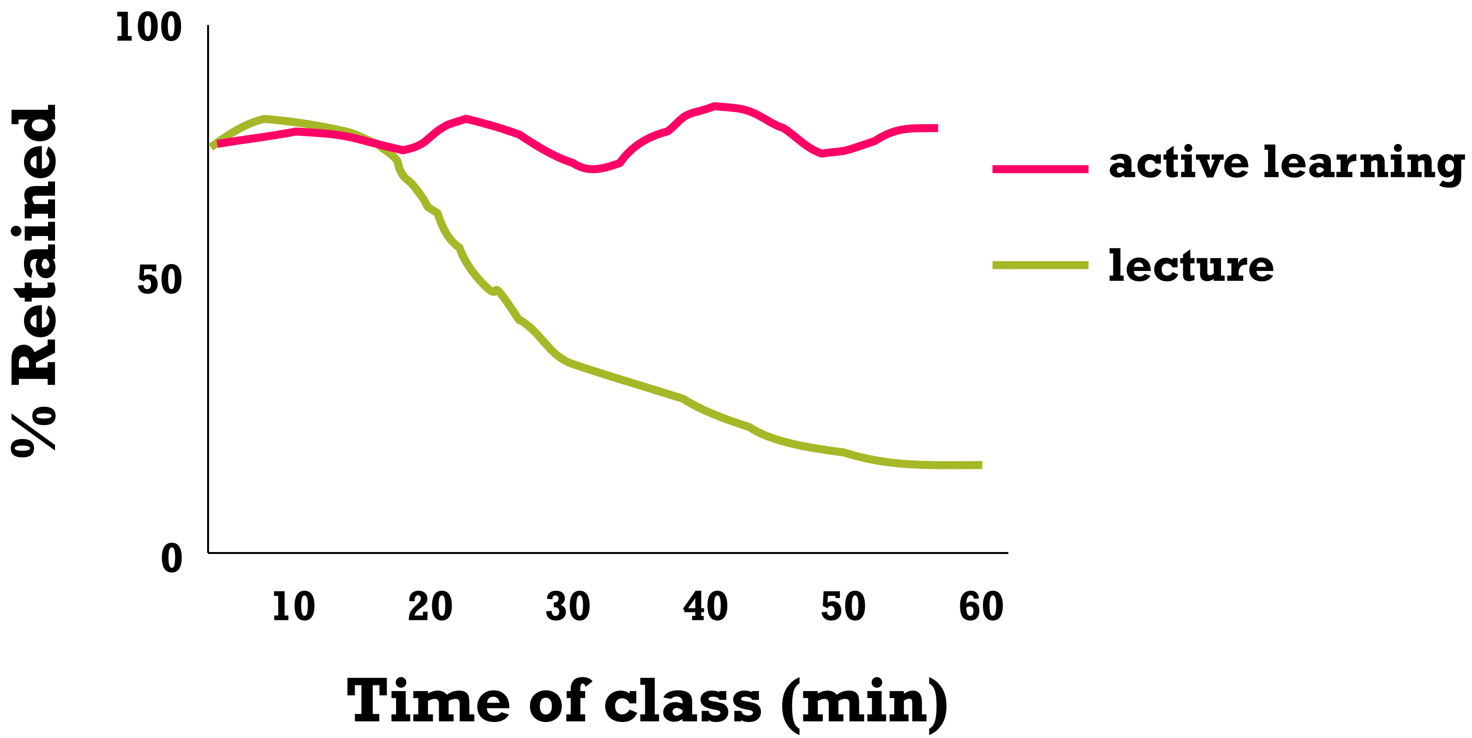
FabLab SchoolNet

Module 2.
Learning by doing. An approach towards vocational education

P.I.R.P.O.S.A.L. Model©

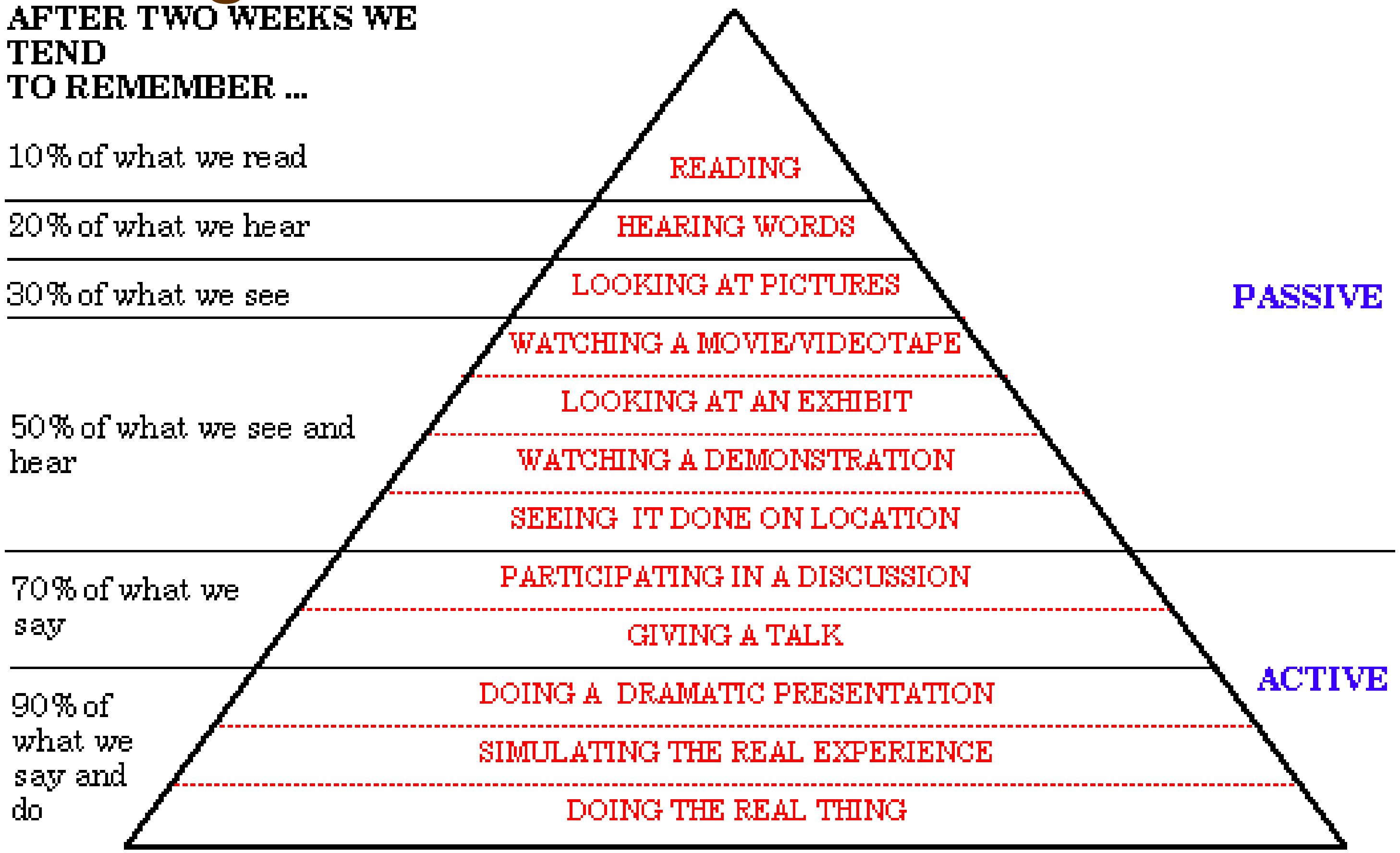
Conceptual/Pedagogical Framework of Integrative STEM Education

What is Active Learning?



From: McKeachie, *Teaching tips: Strategies, research and theory for for college and university teachers,* Houghton-Mifflin (1998)

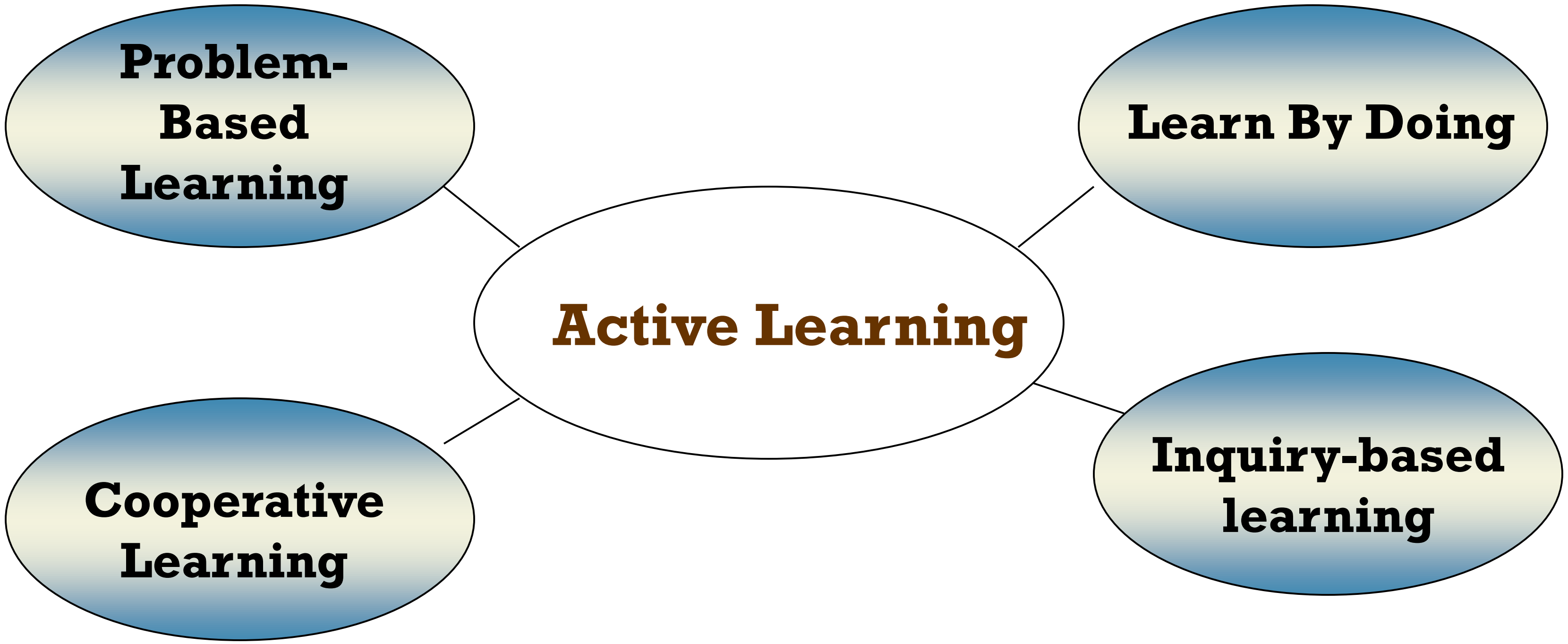
What is Active Learning?



Adapted from: Edgar Dale *Audio-Visual Methods in Teaching*, Holt, Rinehart and Winston.

What is Active Learning?

students **solve** problems, **answer** questions, **formulate** questions of their own, **discuss**, **explain, debate**, or **brainstorm** during class



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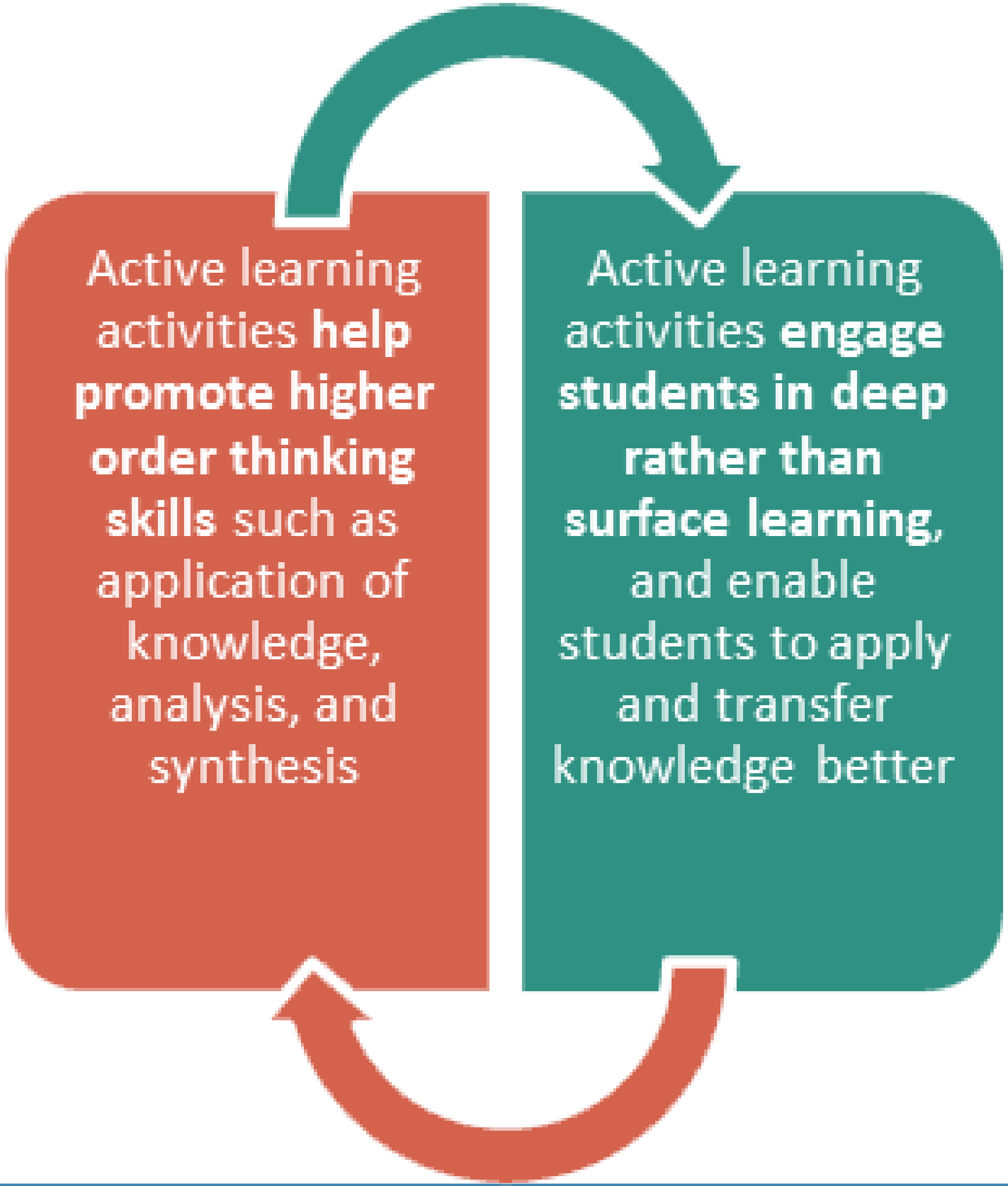
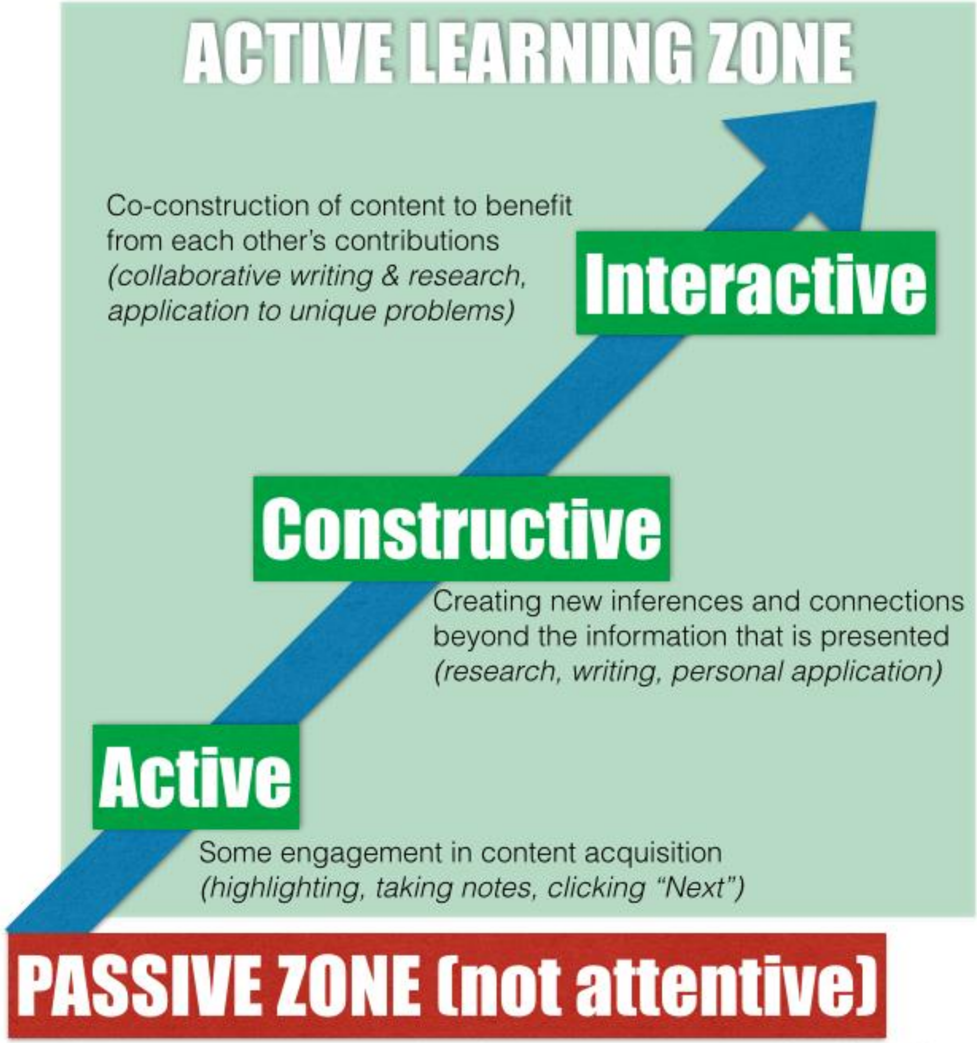
What is the purpose?

- Increase student participation
- Increase student engagement
- Increase student retention
- More student ownership in course
- Less lecturing by instructor
- More exciting classroom experience
- Higher level thinking



Improving Lectures

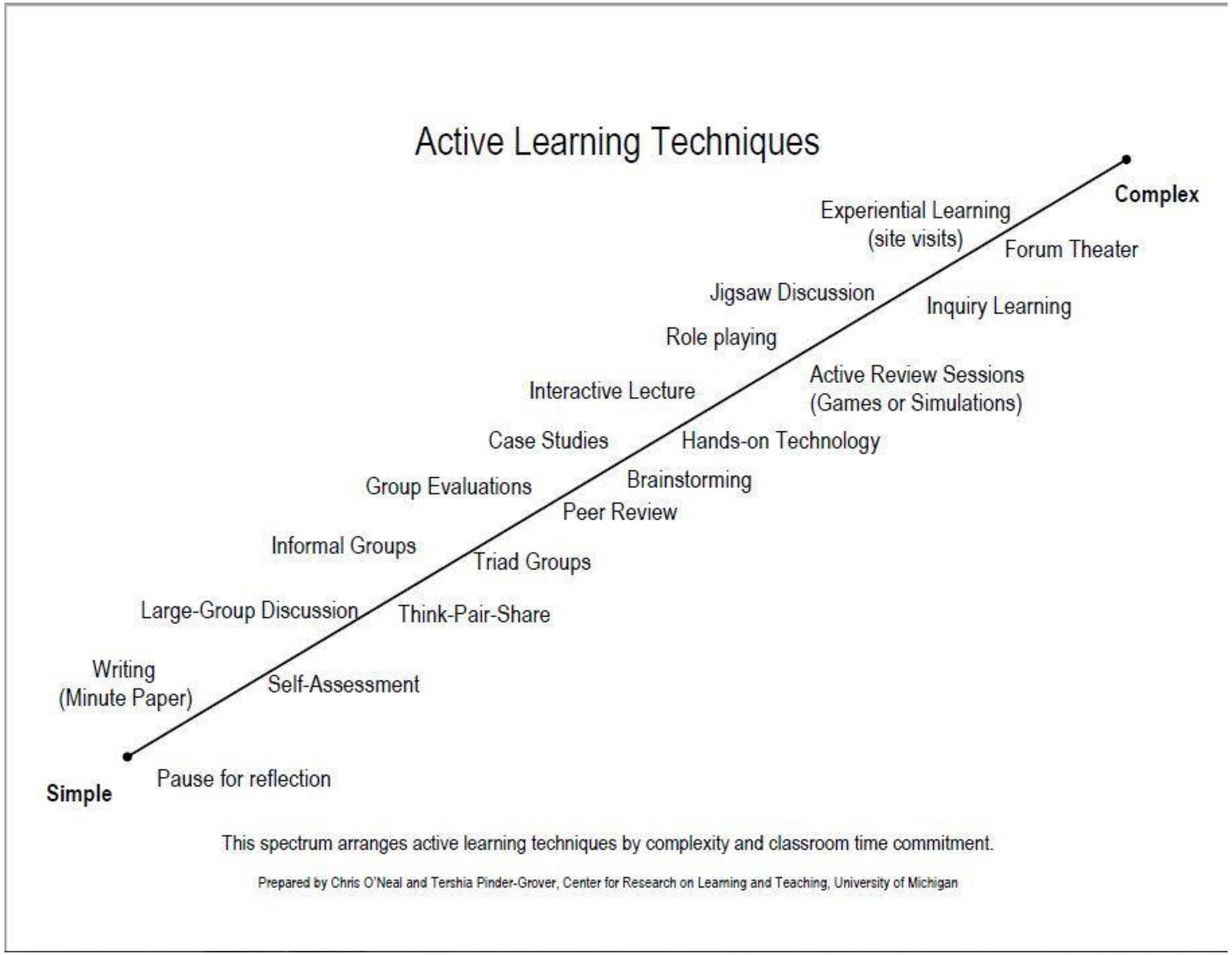
- Plan objectives
- Include graphics, charts, graphs, etc
- Plan what you want to annotate
- Learn students' names
- Cue important points
- Give short activities
- Give students time to generate questions
- Have students summarize major points



Chi, M. T. (2009). Active-constructive-interactive: A conceptual framework for differentiating learning activities. Topics in Cognitive Science, 1(1), 73-105.

Active Techniques

- Think-pair-share (pair-share)
- Role playing, simulations
- Muddiest point/clearest point
- Group quizzing
- Generate lists
- Cooperative learning
- Minute papers and writing assignments
- PBL and case studies
- Concept maps

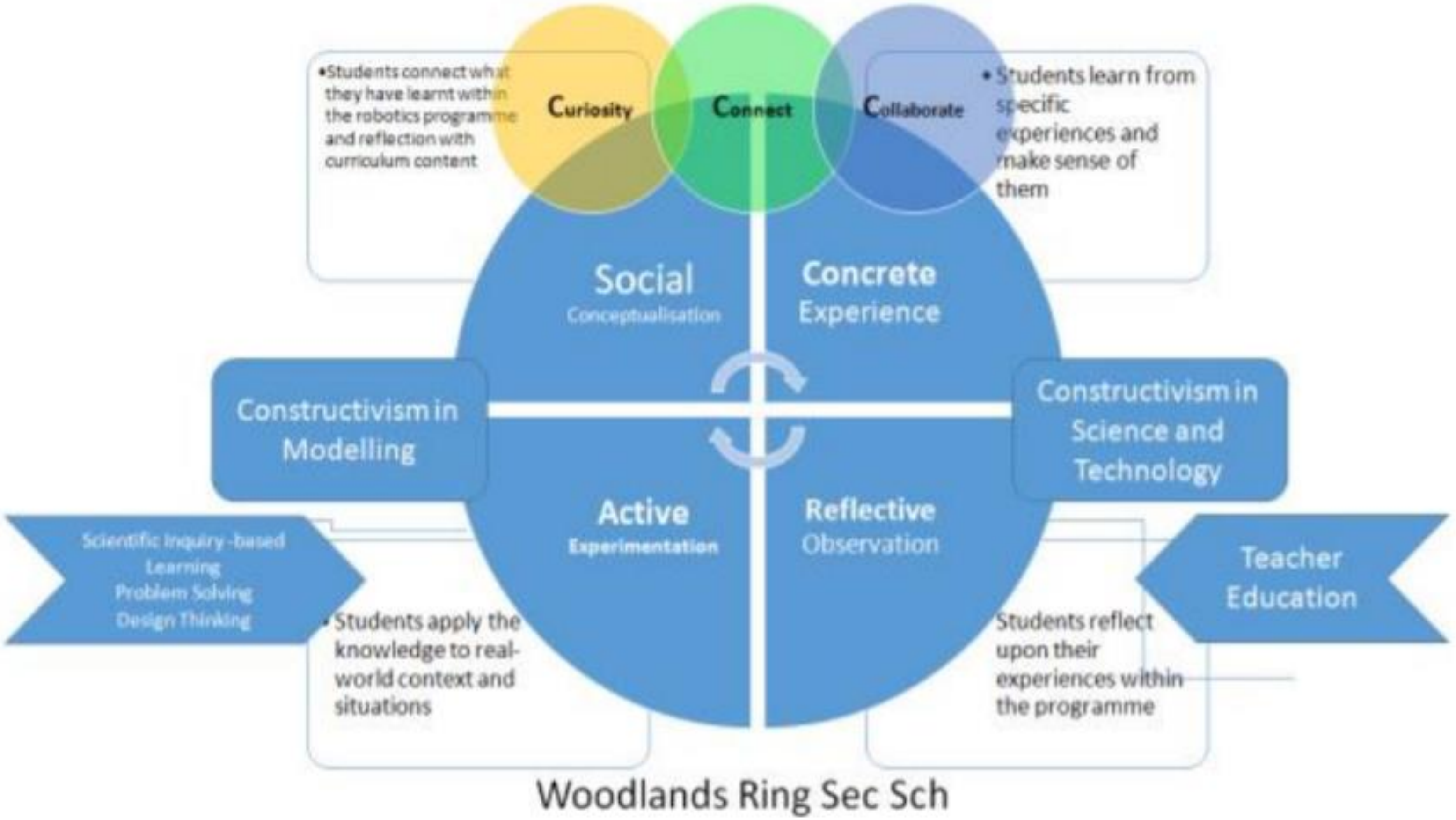


Why teach robotics in schools?

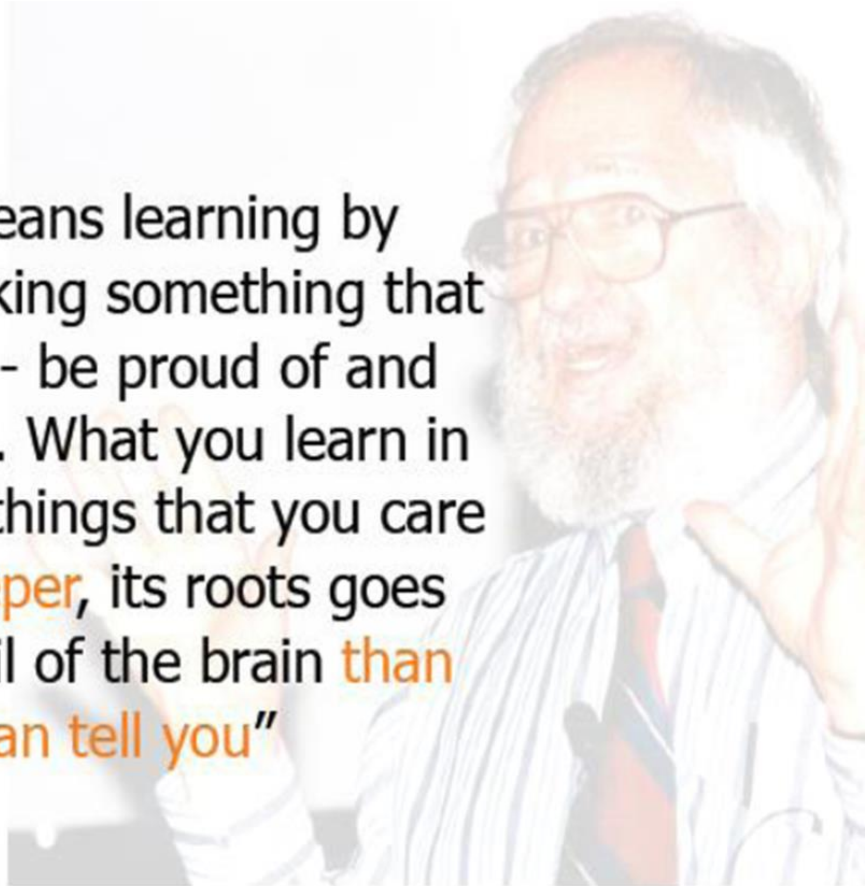
- Robotics is gaining momentum in many schools worldwide. And while it's important to note that teachers who administer courses in this area should advanced knowledge in programming and other skills, students are reaping huge benefits, not just for the present, but also for the foreseeable AI future.
- **Creative thinking**
  - Not many fields of knowledge incorporate creativity and fun simultaneously. Studies have shown that robotics achieves both. In fact, students love to partake in activities in which they have full control, something that is possible with robotics. And when learners are able to do cool stuff, they want to develop more features.
- **Engagement**
  - Hands-on learning activities enhance concentration and attention levels, because the more students learn physical skills, the more they want to continue being in the lesson.
- **Preparedness**
  - With advanced technologies such as artificial intelligence, driverless cars, and spacecrafts taking shape every day, the present generation of students needs to be more prepared for technological changes than any before

Why teach robotics in schools?

- **Programming skills**
  - As artificial intelligence becomes more prevalent in homes, schools, and offices, a little programming knowledge will help everyone understand how these bots work.
- **Perseverance**
  - Creating and programming bots is challenging. However, working through frustration helps students develop a never-give-up attitude. It imparts determination, which is crucial for any technological or scientific undertaking.
- **Teamwork**
  - Robotics incorporates a range of skills, and thus promotes a learning environment for people with different talents. If properly harnessed, it also promotes a culture of teamwork.
- **Fun**
  - Learning about robotics is fun – and as User Experience designers continue to improve how it feels to interact with robots, it will only become more so!
- **Final thoughts**
  - Educators must embrace the latest skills and knowledge for effective teaching. That's why they should embrace robotics, which is breaking new ground in learning methodologies around the world.


Students connect what they have learnt within the robotics programme and reflection with curriculum content
Curiosity
Connect
Collaborate
Students learn from specific experiences and make sense of them
Social
Conceptualisation
Concrete Experience
Constructivism in Modelling
Constructivism in Science and Technology
Active
Experimentation
Reflective Observation
Scientific Inquiry-based Learning
Problem Solving
Design Thinking
Teacher Education
Students apply the knowledge to real-world context and situations
Students reflect upon their experiences within the programme
Woodlands Ring Sec Sch

Seymour Papert
Professor Emeritus, M.I.T., USA



"Constructionism means learning by making something. Making something that you can identify with - be proud of and think - this is my thing. What you learn in the process of making things that you care about sinks much deeper, its roots goes deeper into the subsoil of the brain than what anyone can tell you"

FabLab SchoolNet

Module 3.
Educational Robotics.
Theory and Practice

Robotics

Title: Robotics – Mindstorms NXT platform. Intro to Robotics

Description: Start by asking the students what their definition of "robot" is. Go around the room and come up with various definitions and examples of robots.
Show them a few cool robot videos to get them excited. Battlebots is a good one, as are FRC (FIRST Robotics Competition), FLL (FIRST LEGO League), and other LEGO Mindstorms robots. Battlebots is a competition where teams try to destroy their opponents' robots without getting destroyed themselves. FLL robots are the most similar to the robots students will be building. See the Resources page for further information.
Explain what they will accomplish in the robotics sessions. Tell them the various activities. Tell them that the things they will learn in these sessions will give them a basis for being able to build even cooler robots, like the ones they saw in the videos.

Robot definition

"a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer."

Good YouTube videos

Best of Battlebots

Best of the Best FRC

Amazing LEGO Machines Compilation

Lego Paper Plane Machine

Activities for long version

Build the robot

Drive in a square

Build a remote control

Kick a ball into a goal

Pick something up

Stay on a table

Try to push another robot off a table/out of a ring

Follow a line

Go through a maze

Activities for short version

Build the robot

Drive in a square

Pick something up

Stay on a table

Stop at a line

Go through a maze

Learning objectives: Students will learn what they will cover throughout the lesson series and explore the basic definition of robotics.

Age: 10

Topics: geometry, mathematics, art

Materials: Computer with access to YouTube

Assessment: Not applicable

Total time: 5 hours

Title: Mindstorms NXT platform. Build the Bot

Description: Students will begin the lesson series by building their base robot.
Start by explaining how to build LEGOs. Most students are probably familiar with the concept, but these pieces are different than normal LEGO blocks so it's good to go over it.
Next, divide into teams. Teams of 2 or 3 work best so there's something for everyone to do. Brainstorm ideas for how to work effectively in a group.
Have the students begin building the base robot! These lesson plans are intended to be used with a basic car robot design. Links to Mindstorms User Guides for five possible kits (NXT 1.0, 2.0, Education; EV3 Education, Home) are in the Resources section. Kits generally come with a User Guide—however, some may be designed to build a three motor car, whereas these lessons are designed for a two-motor car, so consulting the appropriate links in the Resources section may be beneficial.
Make sure to encourage creativity. If the User Guide suggests putting treads on the wheels, for example, it is perfectly acceptable to use rubber tires instead.

If possible, robots should be built using only two motors. Students will add the third motor at a later point without the help of the Mindstorms User Guide.
In the Mindstorms User Guide, stop at the point where sensors begin to be added to the robot. Students will add sensors at a later point without the help of the Mindstorms User Guide.
If it looks like students are struggling to work collaboratively, pause about halfway through to discuss their groupwork strategies. Ask what's working, what isn't working, and what can change to maximize efficiency but also collaboration.

Groupwork examples

• One person programs while the other person builds
• One person reads out the necessary pieces while the other finds them
• One person collects pieces while the other person assembles them
• Switching off building sections and programming sections
• Bad example: one person does all the work and the other person watches!

Creativity examples

• If the Mindstorms User Guide says to build the arm such that it moves side to side, change it so it goes backwards and forwards
• If the Guide says to have 3 wheels, change it so it has 4
• If the Guide says to put the ultrasonic sensor at the back of the robot, move it to the front

Learning objectives: Students will learn how to assembly a robot.

Age: 10

Topics: geometry, mathematics, physics.

Materials: Kit of robot parts—includes:
- Building materials
- 2 motors
- 1 brick
Mindstorms User Guide

Assessment: Not applicable

Total time: 2 hours

Title: Robotics – Mindstorms NXT platform. Perfect Square.

Description:

Start by introducing programming. Describe the basic move function, including the difference between steering and tank driving (steering controls both wheels simultaneously, while tank controls them individually). Have students open laptops with EV3 programming software already on the screen. Go to File --> New Project, which will get them to a blank starting screen for the program. Point out where the move block is.

Challenges (once a group has completed one, introduce the next):

- Move 3 rotations and then stop

- Move for 3 seconds and then stop

- For this, if possible, have the groups line their robots up together at the beginning of the run to see if they finish at the same place

- Move in a square of any dimensions

- Move continuously in a square of any dimensions

Groups should complete all of the above challenges by the end of the lesson. If there is still time, groups may proceed to the following challenges.

- Move in a square that is a foot by a foot (either a 12 inch foot, or the length of a student's foot!)

- Move in a square that takes 10 seconds to complete

- If they were using steering move blocks, have them switch to tank and repeat the challenges, or vice versa.

Steering

Motors are controlled together. Direction is changed directly and is indicated by the arrow on the block. Backwards movement is achieved by using a negative number in the power variable on the block.

Tank Driving

Each motor (wheel) is controlled independently. Direction is changed by adjusting the power of the respective motors. Backwards movement is achieved by using a negative number in the power variable on the block.

A more specific overview of the locations of functions on the Move blocks and the instructions to create a new program are contained in the Programming Overview.

Note: For continuous square programs, exact numbers will vary based on size of robot and wheels. For example, it may take 360˚ or even 720˚ rotation to get the robot to make a 90˚ corner, as opposed to the 180˚ shown in the solution.

Perfect Square - Program Solution(s)

Program Flow: 3 Rotations—Move Steering

1. Move Steering: Direction 0, Power 75, Rotations 3
2. Robot will move forward three rotations

Program Flow: 3 Rotations—Move Tank

1. Move Tank: Motor 1 Power 75, Motor 2 Power 75, Rotations 3
2. Robot will move forward three rotations

Program Flow: 3 Seconds—Move Steering

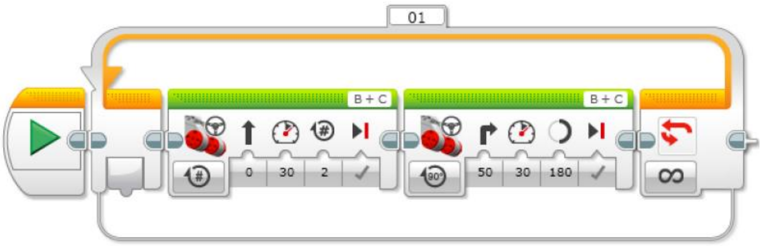
1. Select button under the image of the motors to change from rotations to seconds
2. Move Steering: Direction 0, Power 75, Seconds 3
3. Robot will move forward for three seconds

Program Flow: 3 Seconds—Move Tank

1. Select button under the image of the motors to change from rotations to seconds

2. Move Tank: Motor 1 Power 75, Motor 2 Power 75, Seconds 3

3. Robot will move forward for three seconds



Program Flow: Continuous Square—Move Tank

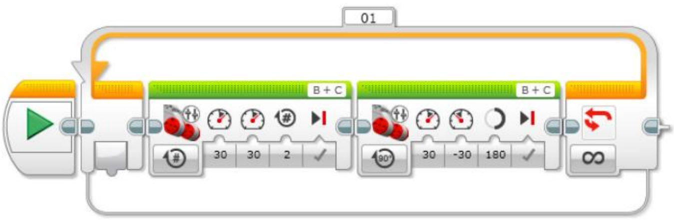
1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Move Tank: Motor 1 Power 30, Motor 2 Power 30, Rotations 2 A. Robot will move forward two rotations

3. Select button under the image of the motors to change from rotations to degrees

4. Move Steering: Motor 1 Power 30, Motor 2 Power -30, Degrees 180 (will vary) A. Robot will turn right

5. Robot will continue to go straight then make a 90° turn to form a square



Program Flow: Continuous Square—Move Steering

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Move Steering: Direction 0, Power 30, Rotations 2 A. Robot will move forward two rotations

3. Select button under the image of the motors to change from rotations to degrees

4. Move Steering: Direction 50, Power 30, Degrees 180 (will vary) A. Robot will turn right

5. Robot will continue to go straight then make a 90° turn to form a square

Learning objectives: Students will learn the basics of programming, starting with programming the robot to move. Concepts Covered: “Move Tank,” “Move Steering,” and “Loop” programming blocks.

Age: 10 and up

Topics: geometry, mathematics, physics, informatics

Materials: K Robot with 2 motors and wheels
Laptop with EV3 software
USB connector

Assessment: Not applicable

Total time: 1.5 hours (long) or 1 hour (short)

Title: Robotics – Mindstorms NXT platform. Remote Control

Description:

Explain the initial concept: Students are building a remote control using two touch sensors that can make their robot go forward, turn left, and turn right. If only one touch sensor is available, the control can simply make the robot move forward if pushed and stop if not pushed.

Start by having students come up with a table of possible robot movements and their correspondence to motor movement. An example is included in the Volunteer Cheat Sheet. Remind students that turning right is controlled by the left motor, not the right motor.

Introduce the Switch block. Explain how to use it with the touch sensor. Allow students to build, program, and test their remote control.

Begin with just the headings, and have students fill in the table. Give them hints if they need them, but don't give away the answers.

Movement/Buttons pushed	Motors used
Forward - both buttons	Both
Right - right button	Left
Left - left button	Right
Stop - no buttons	None

An overview of the Switch block (similar to the commonly used "'if' statement" in regular programming) is contained in the Programming Overview. In this case, the switch will be used to determine whether or not each button is pushed. There are multiple ways of constructing this program. One option is to check each button sequentially; if Button 1 is pushed, run right motor, and if Button 2 is pushed, run left

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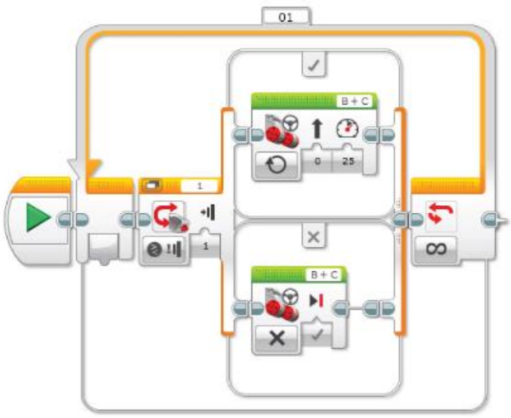
motor. Another option is to nest the Switch blocks; if Button 1 is pushed, check Button 2, and if it's pushed go forward, otherwise go right, etc.

A remote control may look like this. Keep in mind that sensors must be connected via wires to the correct ports on the brick for them to work.

Remote Control - Program Solution(s)

Orientations

Robot driving forward (towards Ports 1-4) Control held directly above robot facing same direction Left-hand button connects to Port 2, makes robot turn left, and controls Motor B (right wheel). Right-hand button connects to Port 1, makes robot turn right, and controls Motor C (left wheel).



One Touch Sensor

Program Flow: One Touch Sensor

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the state of the touch sensor (Port 1) using a switch

A. If the sensor is pressed, go to the top part of the switch

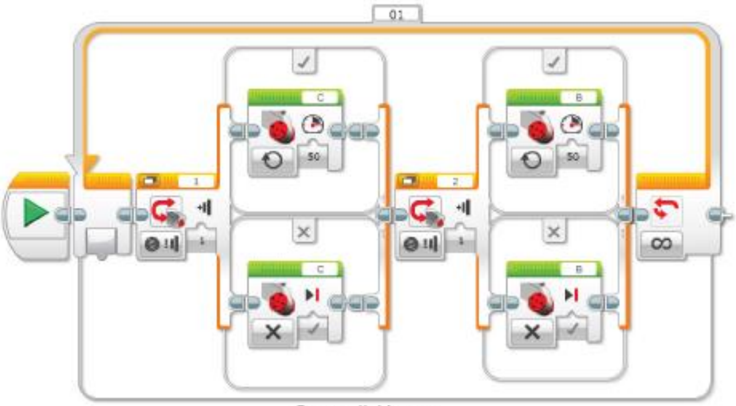
i. Move Steering: Direction 0, Power 25, infinite rotations

ii. Robot will move forward until button is released

B. If the sensor is not pressed, go to the bottom part of the switch

i. Move Steering: no motion

ii. Robot will not move until button is pressed



Sequential Loops

Program Flow: Sequential Loops

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the state of the right touch sensor (Port 1) using a switch

   A. If the sensor is pressed, go to the top part of the switch

   i. Large Motor (C): Power 50, infinite rotations

   ii. Robot's left wheel will turn

   B. If the sensor is not pressed, go to the bottom part of the switch

   i. Large Motor (C): no motion

   ii. Robot's left wheel will not turn

3. Check the state of the left touch sensor (Port 2) using a switch

   A. If the sensor is pressed, go to the top part of the switch

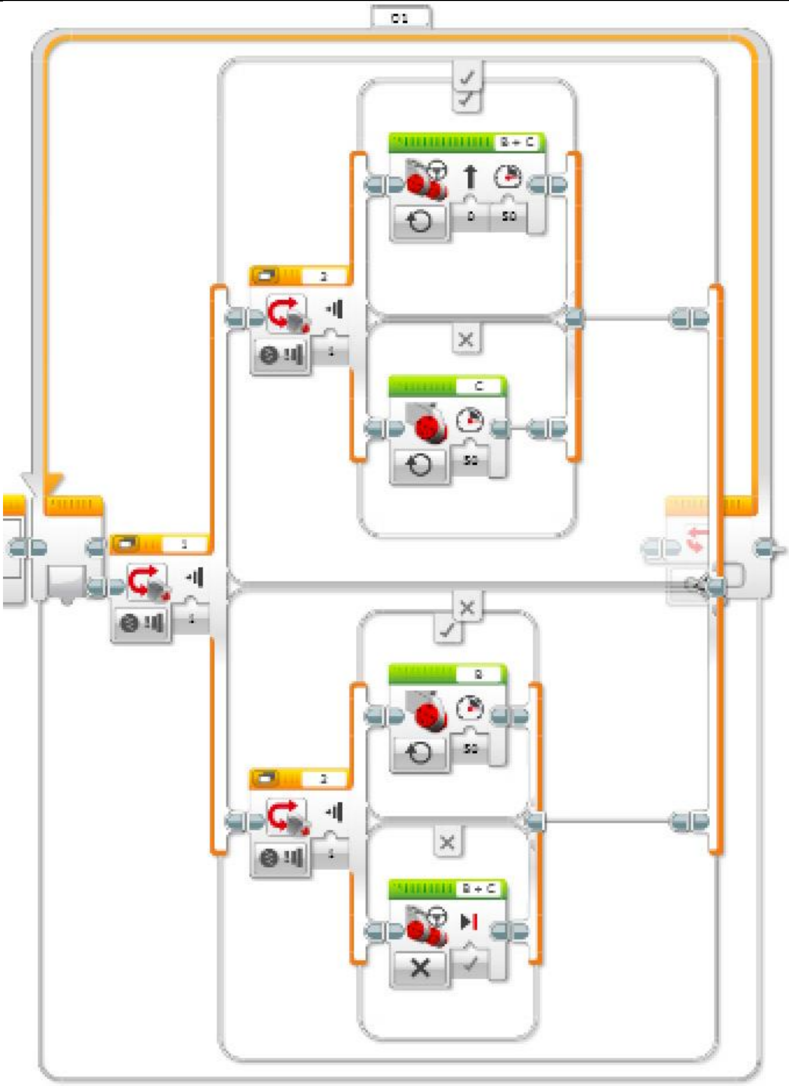
   i. Large Motor (B): Power 50, infinite rotations

   ii. Robot's right wheel will turn

   B. If the sensor is not pressed, go to the bottom part of the switch

   i. Large Motor (B): no motion

   ii. Robot's right wheel will not turn



Program Flow: Nested Loops

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the state of the right touch sensor (Port 1) using a switch

3. If the sensor is pressed, go to the top part of the switch

A. Check the state of the left touch sensor (Port 2) using a switch

i. If the sensor is pressed (both are pressed), go to the top part of the switch

a. Move Steering: Direction 0, Power 50, infinite motion

b. Robot will continue moving forward until a button is released

ii. If the sensor is not pressed (only right button is pressed), go to the bottom part of the switch

a. Large Motor (C): Power 50, infinite motion

b. Robot will turn right

4. If the sensor is not pressed, go to the bottom part of the switch

A. Check the state of the left touch sensor (Port 2) using a switch

i. If the sensor is pressed (only left button is pressed), go to the top part of the switch

a. Large Motor (B): Power 50, infinite motion

b. Robot will turn left

ii. If the sensor is not pressed (no buttons are pressed), go to the bottom part of the switch

a. Move Steering: no motion

b. Robot will remain stopped until a button is pressed

Learning objectives: Students will learn more programming commands and experiment with the touch sensor by building a remote control for their robot car. Concepts covered: Building without instructions, “Switch” programming block, Touch sensor.

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Two touch sensors per group (adaptations can be made if there is only one)
Two wires to connect control to robot
Extra LEGOs to build the remote control

Assessment: Not applicable

Total time: 1 hour

Title: Robotics – Mindstorms NXT platform. Goal Scorer

Description: Explain the initial concept: Students are adapting their robot and programs to be able to kick a ball into a goal. Start by discussing strategies for the robot’s motion, neglecting the programming aspect for the time being. Have the students come up with a design for the arm, then build it. If they struggle to find a design, hint that using another motor and some kind of gear mechanism could help. Consult the volunteer cheat sheet for more detailed advice.

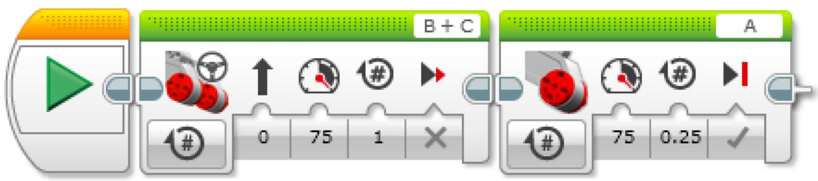
Once the mechanism has been built, students may begin programming. Before testing their program, they should predict what their arm will do—will it move fast? Go in a full circle? Go in many circles? Fall off? These questions will force them to think about attributes like power and rotation limits that they may not have considered initially.

The easiest way to complete this challenge is to build an arm attached to the side of the robot via a motor. The arm will be mounted on the motor and will rotate when the motor rotates. A very rudimentary arm may look like this. Arms may be much more creative, involving gears and more suitable shapes.

If students are struggling to come up with that idea themselves, give them a spare motor and have them play around with it. Discuss how a motor's rotation can translate to an arm's rotation.

Program Solution(s) - Goal Scorer

Note: Brake on the first block is set to Off to enable the robot to coast into the ball.



Program Flow

1. Move Steering: Direction 0, Power 75, Rotations 1

   A. Robot will move forward towards ball and coast

2. Large Motor (A): Power 75, Rotations .25

   A. Robot arm will swing and kick ball

Learning objectives: Students will build and program their robots to be able to kick a ball into a goal. Concepts covered: building and programming with a third motor.

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Third motor plus connecting wire*
Materials to build robot arm
Some kind of ball (can be part of provided kit, paper or tinfoil ball, bouncy ball, etc)
Some kind of goal (can be part of provided kit, a paper target to hit, an empty cup laying flat, etc)

Assessment: Have students test and revise their programs. If there is remaining time, students may have a contest to see who can kick the ball a) farthest and b) most accurately.

Total time: 1.5 hours

Title: Robotics – Mindstorms NXT platform. Picker-Upper

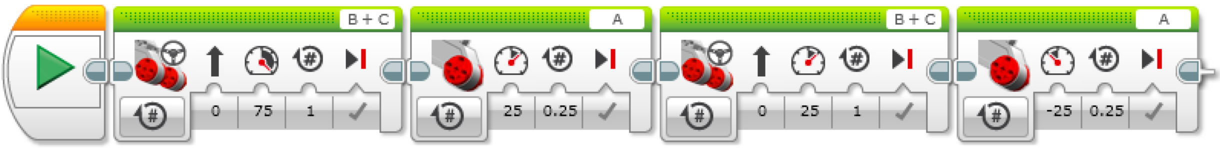
Description: Explain the initial concept: Students are adapting their robot and programs to be able to pick up an object.
If the arm is not already built (short lessons): Start by discussing strategies for the robot's motion, neglecting the programming aspect for the time being. Have the students come up with a design for the arm, then build it. If they struggle to find a design, hint that using another motor and some kind of gear mechanism could help. Consult the volunteer cheat sheet for more detailed advice.

If the arm is already built (long lessons): Start by discussing adaptations that will need to be made to the arm. Does it need to change in shape? Size? Speed? Rotations? Have students come up with answers.

Once the mechanism has been designed and built/adapted, students may begin programming. Have them test and revise their programs. If there is remaining time, students may try to program the robot to drive a short distance with the object and deposit it back on the floor.
For help with building the arm, see the cheat sheet from the previous lesson.

Arms should move fairly slowly. Robots will have to be lined up precisely with their target, as this program does not include any sort of vision capabilities. Arms will also need to be small enough to be able to hook onto whatever they are picking up.

Program Solution(s) - Picker-Upper
Note: Power has been significantly adjusted to ensure the stability of the object that is being picked up.



Learning objectives: Students will build and program their robot to be able to pick an object up using a hook mechanism with one motor and arm. Concepts covered: Designing a robot to complete a more precise task.

Program Flow

1. Move Steering: Direction 0, Power 75, Rotations 1
   A. Robot will move forward and hook onto object
2. Large Motor (A): Power 25, Rotations .25
   A. Robot arm will lift object
3. Move Steering: Direction 0, Power 25, Rotations 1
   A. Robot will move forward with object
4. Large Motor (A): Power 25, Rotations .25
   A. Robot will lower object

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Object to be picked up (can be hollow rectangle provided in kit, object made of LEGOs, empty cup laying flat, etc—must have some kind of hole that the robot's arm can fit into)

If third arm not already built:

- Third motor plus connecting wire

- Materials to build robot arm

Assessment: Not applicable

Total time: 1 hour (long), 1.5 hours (short)
Note: extra half hour for short version is for building the arm

Title: Robotics – Mindstorms NXT platform. Table Bot

Description: Explain the initial concept: Students are programming their robot to drive around a table without falling off.

Start by introducing the ultrasonic sensor and how it works. Ask students to brainstorm possible ways to write the program. The Volunteer Cheat Sheet has a more thorough explanation of the program.

Allow students time to mount the sensor to their robot—it should be aimed at the ground and be far enough ahead of the robot's wheels such that the robot has time to stop once it senses the ground.

Explain the Display programming block. This will allow students to see the threshold between the table and the ground.

Next, have the students program the robot to stop once it reaches the edge of the table. Once that is successful, have them program it to back up and turn around so that it will continuously drive around the table, backing up and turning every time it reaches an edge.

The ultrasonic sensor is covered in more detail in the Sensors Overview. For this challenge, the sensor will be used to determine the distance between the robot and either the table or the ground. If the distance is short (i.e. less than three inches), the robot will drive forward. If the distance is longer than that, the robot will stop and eventually back up and turn.

To see sensor readings and determine the parameters, it is convenient to use the Display block. The Display block is what it sounds like: it displays the sensor readings on the screen of the brick. This can be a helpful tool for debugging a program.

The program itself will rely on a Switch block, but will incorporate Display into its functioning. See the solution for details.

Program Solution(s) - Table Bot

Program Flow

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the reading of the ultrasonic sensor

3. Display the reading

4. Check the state of the sensor using a switch

5. If the reading is below 5 inches (robot is on the table—numbers wll vary), go to the top part of the switch

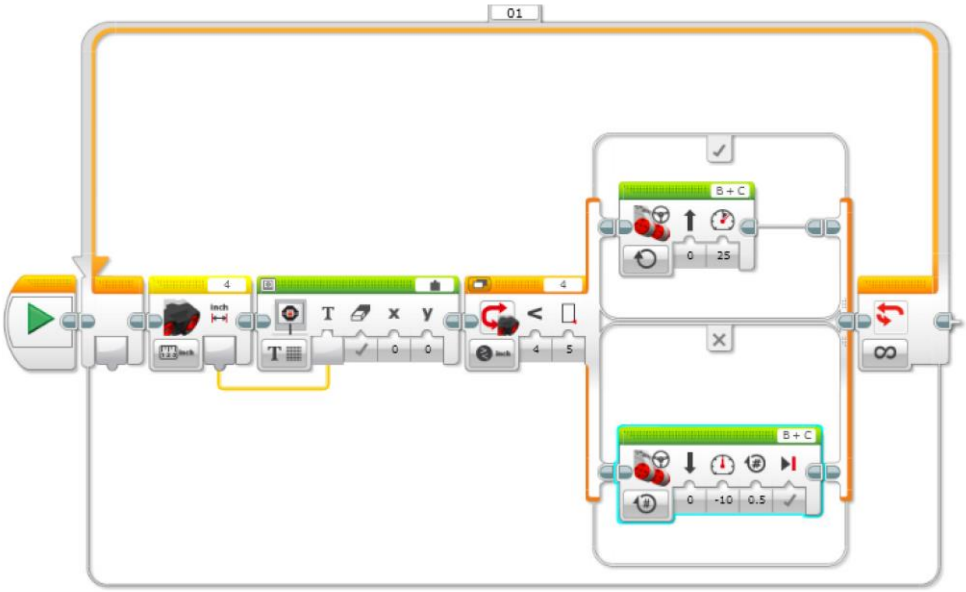
    A. Move Steering: Direction 0, Power 25, infinite motion

    B. Robot will continue moving forward until the ultrasonic sensor is triggered

6. If the reading is above 5 inches (robot has reached the edge of the table—numbers will vary), go to the bottom part of the switch

A. Move Steering: Direction 0, Power -10, Rotations .5

B. Robot will back up



Learning objectives: Students will build and program the robot so that it is able to stay on a table without falling off. Concepts covered: Ultrasonic sensor, "Display" block.

Age: 10 up

Topics: geometry, mathematics, art

Materials: Assembled robot, laptop, USB
Ultrasonic sensor and connecting wire
Table, desk, or other elevated surface

Assessment: Not applicable

Total time: 1 hour

Title: Robotics – Mindstorms NXT platform Line Stopper

Description: Explain the initial concept: Students are programming their robot to stop once it reaches a line.

Start by introducing the light sensor and how it works. Point out the connection between this program and the Table Bot program—they are essentially the same, just with different sensors.

Allow students to mount the sensor and write the program. Suggest that they use the display block to see the difference between the sensor's perception of light and dark.If robots are not stopping despite having the correct readings, suggest that students slow their robots down (lower the power) to give the sensor time to register and communicate the data to the brick.

For EV3 brick + either NXT or EV3 light/color sensor:

Use the same method for determining the light threshhold as with the ultrasonic sensor. Use a Color Sensor block connected to a Display block to display the sensor reading. For this program, it is advisable to use the Reflected Light Intensity setting: this will measure the amount of light reflected from the surface.

For NXT brick + NXT light sensor:

The method for determining the light threshhold is similar but not identical. Because the NXT light sensor differs from the EV3 color sensor, there is an adjustment that must be made in order to display the correct reading. It is shown below. It uses the NXT Sound Sensor block to take the reading and the color sensor block to turn on the sensor.

The NXT Sound Sensor block does not come as part of the software package; it must be downloaded separately from the LEGO website. See the Resources page for download instructions. The NXT color sensor functions the same way as the EV3 color sensor.

Sample readings (EV3 Sensor/NXT Brick are not compatible):

	White paper	Blue tape	Black marker
EV3 Sensor/EV3 Brick	65	10	10
NXT Sensor/EV3 Brick	55	45	40
NXT Sensor/NXT Brick	65	50	50

Note: Readings will vary from the above samples based on the distance between the sensor and the surface.

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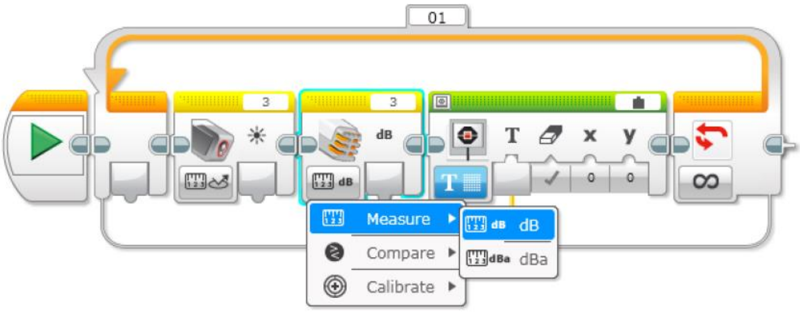
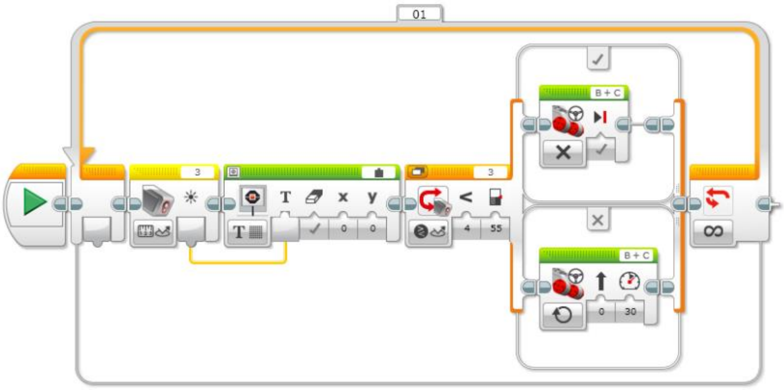


Program Solution(s) - Line Stopper



Program Flow: EV3 Brick and/or Sensor

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the reading of the light/color sensor (Port 3) on the Reflected Light Intensity setting

3. Display the reading

4. Check the state of the sensor using a switch

5. If the reading is below 55 (meaning it is on a line—numbers will vary), go to the top part of the switch

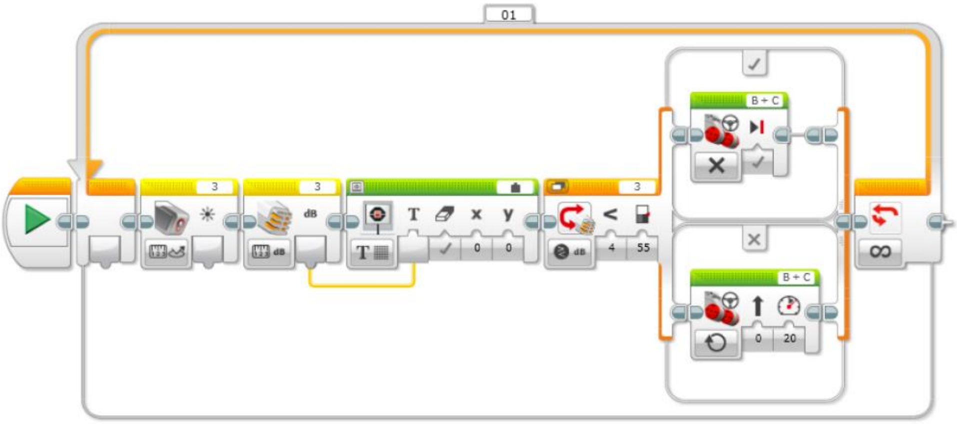
   A. Move Steering: No motion

   B. The robot will stop when it reaches the line

6. If the reading is above 55 (meaning it is not on a line—numbers wil vary), go to the bottom part of the switch

   A. Move Steering: Direction 0, Power 20, infinite motion

   B. Robot will continue forward until the light sensor is triggered



Program Flow: NXT Brick with NXT Sensor

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the reading of the light sensor (Port 3) on the Reflected Light Intensity setting

3. Use NXT Sound Sensor block (Port 3) to display the reading of the light sensor

4. Check the state of the sensor using a switch

5. If the reading is below 55 (meaning it is on a line—numbers will vary), go to the top part of the switch

   A. Move Steering: No motion

   B. The robot will stop when it reaches the line

6. If the reading is above 55 (meaning it is not on a line—numbers wil vary), go to the bottom part of the switch

   A. Move Steering: Direction 0, Power 20, infinite motion

   B. Robot will continue forward until the light sensor is triggered

Learning objectives: Students will build and program the robot so that it is able to stop at a thick dark line on a table. Concepts covered: Light sensor and calibration.

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Light sensor and connecting wire
Thick dark line for robot to stop at (can be tape or marker on paper or any other kind of

thick dark line on a light surface)

Assessment: Not applicable

Total time: 1 hour

Title: Robotics – Mindstorms NXT platform. Sumo Bot

Description: Explain the initial concept: Similar to Battlebots, which they watched in the beginning of the lesson series, students are building their robots to push their opponents out of a ring.
Students must use the light sensor to ensure that they remain inside the ring. Allow them to program their robot. Suggest that the code will look similar to the code for the Table Bot.

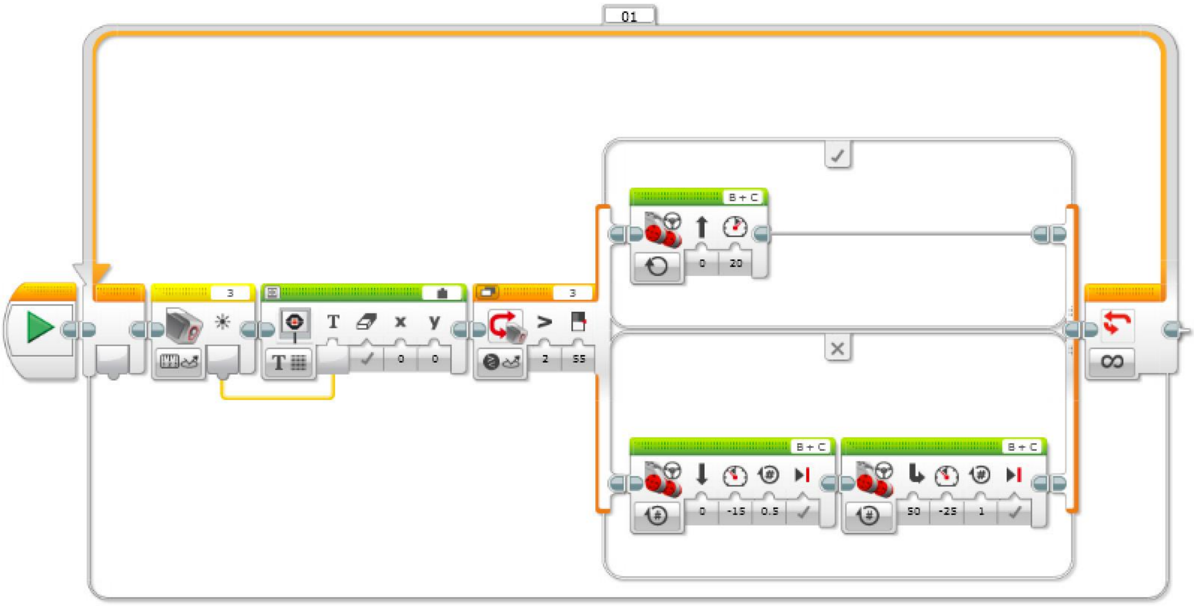
Allow students time to construct adaptations to their robot. Examples include bumpers to fend off opposing robots, slides to go under opponents' wheels, etc.

The rules are as follows: Robots may break off pieces of their opponents' assembly, but they may not break the LEGO pieces themselves. Robots are considered "out" when any part of the robot that is touching the ground goes outside the ring. Robots must win two out of three matches to win the round, and they must win two out of three rounds to win the overall competition. The robot who has won the previous match must place their robot on the field first; the losing team then has the freedom to orient their robot any way they like.

Students will have no time between matches to fix their robots, but depending on how much time remains in the session, give them 15-30 minutes to adapt their robots between rounds.
The program will be essentially the same as the Table Bot program, just using the light sensor instead of the ultrasonic sensor.

Students can get very creative with their adaptations. They often enjoy coming up with different weapon ideas. For example, they may use a third motor as an arm, building off their goal scorer construction.

Sumo Bot - Program Solution(s)
Note: for an NXT brick and light sensor, the same trick with the Sound block (as used in Lesson 7) will need to be used along with the Color Sensor blocks shown in this program. All sensors should be using Port 3.



Program Flow

1. Surround the entire program with an infinite loop so it will continue indefinitely

2. Check the reading of the light/color sensor on the Reflected Light Intensity setting

3. Display the reading (if NXT brick + sensor, use Sound block as the display)

4. Check the state of the sensor using a switch

5. If the reading is above 55 (meaning it is not on a line—numbers will vary), go to the top part of the switch

   A. Move Steering: Direction 0, Power 20, infinite motion

   B. The robot will continue straight until the light sensor is triggered

6. If the reading is below 55 (meaning it is on a line—numbers wil vary), go to the bottom part of the switch

   A. Move Steering: Direction 0, Power -15, Rotations 0.5

   B. Move Steering: Direction 50, Power -25, Rotations 1

   C. Robot will move backwards and turn left

Learning objectives: Students will build and program the robot so that it is able to push an opponent's robot out of a ring. Concepts covered: building without instructions, practical programming.

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Light sensor and connecting wire
Ring for robots to compete in (can be tape or marker on paper or floor or other dark ring on light surface)—ring can be any shape and should be 2-3 feet per side/in diameter

Assessment: Not applicable

Total time: 2 hours

Title: Robotics – Mindstorms NXT platform. Maze Navigator

Description: Explain the initial concept: Students are programming their robots to navigate an unknown maze; they may not see the maze before programming the robot.
Give students a sample (easy) maze on paper. Have them discuss strategies for being able to complete the maze, keeping in mind that "just knowing" or "seeing the path" is not an option for the robot.

Suggest that following the right wall of the maze will always eventually lead to the solution. Have students try the sample maze using that strategy. Next, have them think about a robot using this strategy to navigate a maze. They should realize that at some point the robot will bump into a wall.

Ask them for ideas on how to deal with this scenario. If they do not come up with anything, suggest that they use the touch sensor as a sort of bumper to bounce off the walls.

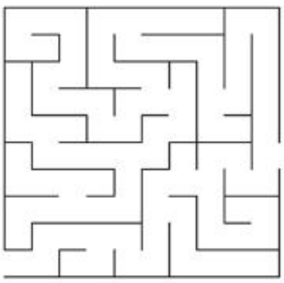
Allow students to program their robots using the ultrasonic sensor and touch sensor to follow the right wall of a maze. They must also adapt the placement of the sensors to be useful. An example is included in the Volunteer Cheat Sheet.

While students are programming, construct the simple maze. It must be wide enough for the robot to comfortably turn around and sturdy enough for a robot to bump into the side without breaking the maze. It does not need to involve more than a few turns. An example is included in the Volunteer Cheat Sheet.

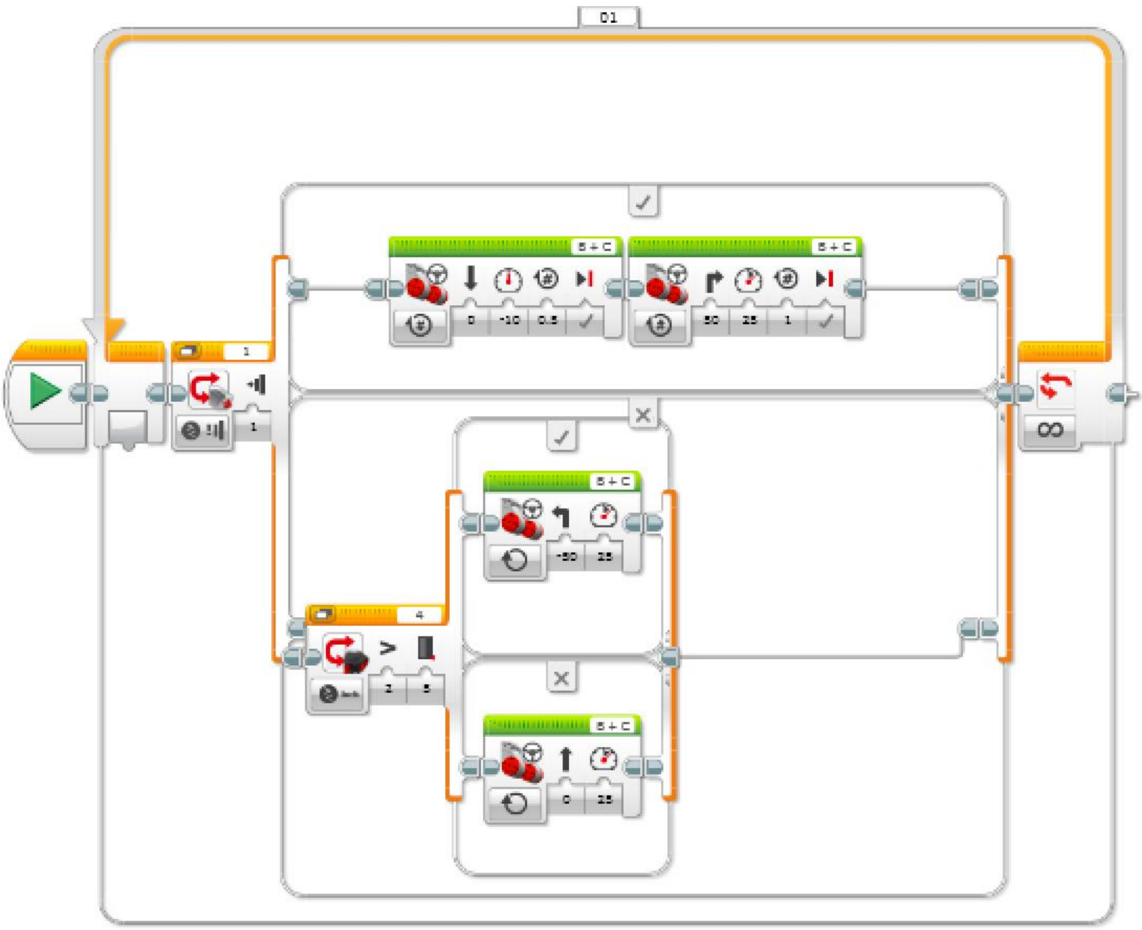
Allow students to test their robots in the maze. Give them time to make adjustments and adaptations and try again. If there is time, have students compete against each other or themselves to see who can finish the maze in the shortest amount of time.
This program is based on the assumption that robots only have one ultrasonic sensor and one touch sensor.

The simplest way to do this is to mount the ultrasonic sensor facing to the right and the touch sensor at the front of the robot. As long as the ultrasonic sensor is within a certain distance of the right wall of the maze (i.e., one inch), continue forward. If the touch sensor bumps into something (the wall ahead), have the robot back up, turn 90˚ to the left, and continue. If the ultrasonic sensor gets out of range of the right wall, have the robot turn to the right until it gets back in range, then continue forward.

It will likely be easiest to construct the maze out of overturned desks or cardboard taped to chair or desk legs; the walls have to be sturdy enough to withstand robots bumping into them. Cardboard boxes may also be weighted with textbooks for added stability. The maze only needs to have two or three turns. [Left: sample paper maze. Right: sample robot maze—path indicated by black lines.]



Maze Navigator - Program Solution(s)



Program Flow

1. Surround the entire program with an infinite loop so it will continue indefinitely
2. Check the state of the touch sensor (Port 1) using a switch
3. If the touch sensor is pressed (robot has hit a wall), go to the top part of the switch

   A. Move Steering: Direction 0, Power -10, Rotations 0.5

   B. Move Steering: Direction 50, Power 25, Rotations 1

   C. The robot will move backwards and then turn right
4. If the touch sensor is not pressed, go to the bottom part of the program

   A. Check the state of the ultrasonic sensor (Port 4) using a switch

      i. If the distance between the sensor and the maze is greater than 5 inches (robot is going away from wall), go to the top part of the switch

         a. Move Steering: Direction -50, Power 25, infinite motion

         b. The robot will turn left

      ii. If the distance between the sensor and the maze is less than 5 inches (robot is still close to the wall), go to the bottom part of the switch

         a. Move Steering: Direction -0, Power 25, infinite motion

         b. The robot will move straight until it triggers the touch sensor or ultrasonic sensor switches

Learning objectives: Students will program their robot to navigate a maze using the ultrasonic sensor. Concepts covered: Extensive programming.

Age: 10 up

Topics: geometry, mathematics, physics, informatics

Materials: Assembled robot, laptop, USB
Ultrasonic sensor and connecting wire

Simple maze (can be constructed from overturned desks, blocks of wood, etc)

Paper maze for example

Assessment: Not applicable

Total time: 3 hours

RESOURCES

To use the NXT Sound Sensor block with EV3 software (necessary to use the NXT light sensor with the NXT brick):

https://www.lego.com/en-us/mindstorms/downloads (near the bottom of the page)

To install the block into the software, go to Tools --> Block Import in the menu bar at the top of the screen. This will bring a pop-up window. Click Browse, then select the block you wish to import. Select Import. The software must be restarted after downloading a new block for it to appear. A screenshot is shown on the next page.

To purchase LEGO components and Mindstorms sensors/accessories:

shop.lego.com

To download Mindstorms software:

EV3 Education (recommended): https://education.lego.com/en-us/downloads/mindstorms-ev3

EV3 Home: https://www.lego.com/en-us/mindstorms/downloads/download-software

To view Mindstorms User Guide (robot assembly instructions):

NXT 1.0: http://www.nxtprograms.com/castor_bot/steps.html

NXT 2.0: http://www.nxtprograms.com/NXT2/castor_bot/steps.html

NXT Education (recommended): http://tinyurl.com/NXT-edu-download

EV3 Education (recommended): http://tinyurl.com/EV3-edu-download

EV3 Home (adaptation of EV3 Education build): http://tinyurl.com/EV3-adaptation

For more information and resources:

Mindstorms: https://www.lego.com/en-us/mindstorms

Girl Scouts: http://www.girlscouts.org

FIRST Robotics: https://www.firstinspires.org

FIRST LEGO League: https://www.firstinspires.org/robotics/fll

Battlebots: http://www.battlebots.com

FabLab SchoolNet

Module 4.
3D Printing.
Theory and Practice

3D1

Title: Fundamentals of solid geometry and use of spatial intelligence

Within the "PON" Project "Il futuro è già qua"_Modulo "Noi piccoli artigiani" ("The future is already here" Module:"We young artisans")

Description:

Starting from 3D modeling with the "SugarCAD" software, the students of the fifth grade, have learned to create physical objects, conceived and designed by them, through the use of the filament 3D printer. "*Spatial intelligence is the ability to draw accurate conclusions from observing a three-dimensional (3D) environment. It involves interpreting and making judgements about the shape, size, movement, and relationships between surrounding objects, as well as the ability to envision and manipulate 3D models of things that are not immediately visible." (https://www.wisegeek.com/what-is-spatial-intelligence.htm)*

Learning objectives:

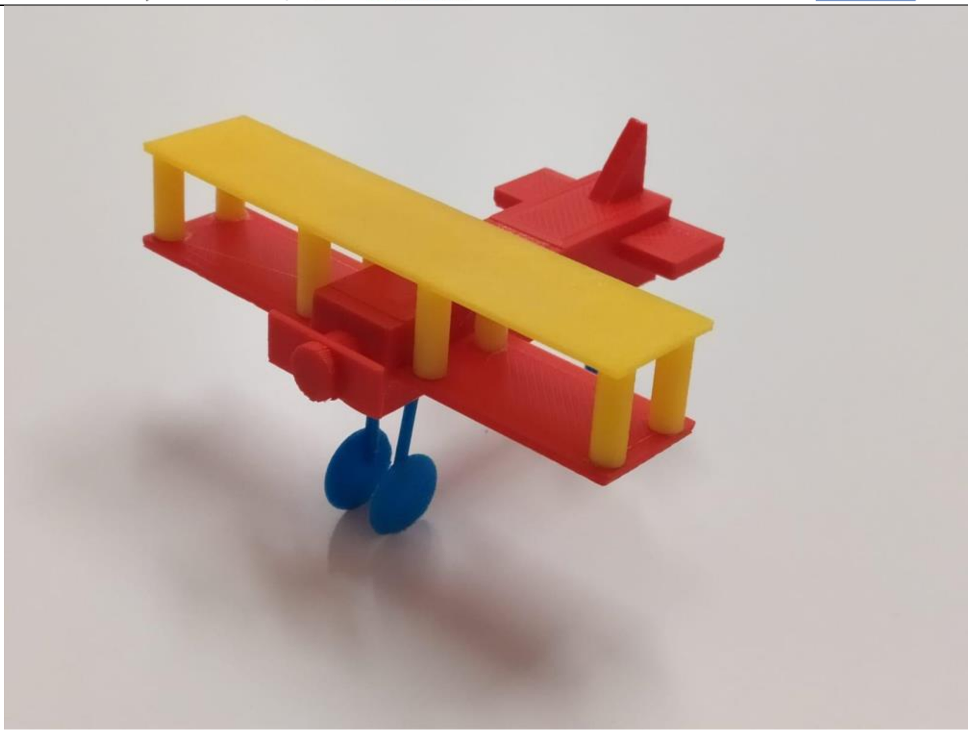
knowledge of the main solid forms, of their combinations through Boolean operations and of the concepts of three-dimensionality and proportion.

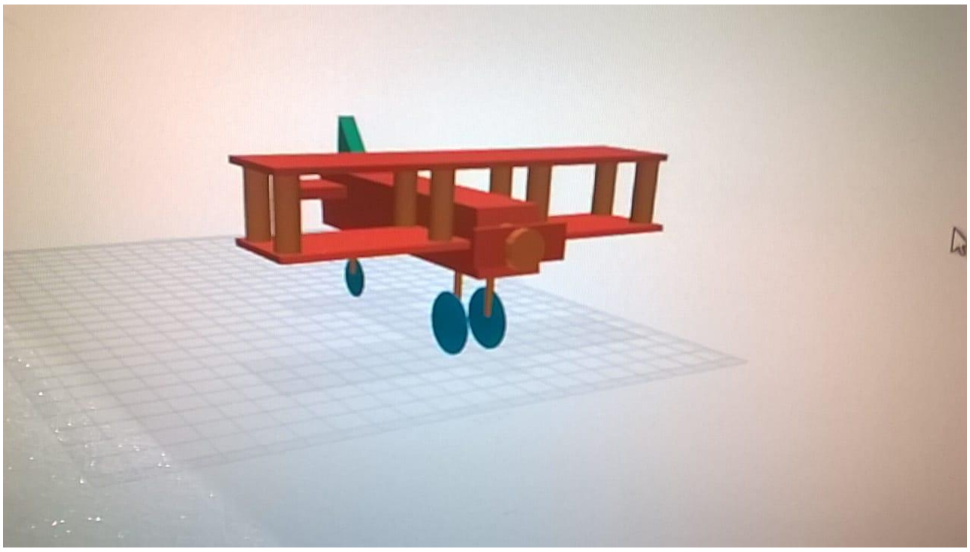
Age: 10

Topics: geometry, mathematics, art

Materials: computer, 3D modeling software, 3D printer, 3D pen

Assessment: the training course, lasting 30 h, aimed at 25 students from the 5th grade of primary school, concluded with positive results regarding the ability of all participants, who acquired the skills necessary for their autonomous use of 3D modeling software, for the realization of physical objects starting from original ideas, taking advantage of geometry, mathematics and creativity. Among the participants, there was also a child with Asperger syndrome, who has showed a very strong interest and strong three-dimensional processing skills.





3D2

Title: "Solid-parametric 3D modeling"

Within the "PON" Project "Stare bene a scuola, stare bene insieme" Modulo "Stampa 3D, Un gioco da ragazzi!" ("Feeling good at school, getting along well" Module: "3D printing, a child's play"), Vocational School "Salvo D'Acquisto", Begheria

Description:
The students have deepened and put into practice their knowledge concerning geometry and mathematics, through the use of solid-parametric modeling software (Autodesk Fusion 360). This type of three-dimensional modeling, widely used in the world of industrial production, makes it possible to design objects of complex shape, managing the construction steps in a parametric manner, therefore with the possibility of varying the dimensional parameters of a given construction operation without having to modify the whole three-dimensional model.

Learning objectives:
knowledge of additive manufacturing technologies; of solid-parametric 3D modeling; application of 3D FDM printing to the prototyping of school design ideas.

Age: 14-17

Topics: geometry, technology, computer science, mathematics

Materials: computer, 3D modeling software, 3D printer

Assessment: the training course, lasting 30 h, aimed at 25 students from the 5th grade of primary school, concluded with positive results regarding the ability of all participants, who acquired the skills necessary for their autonomous use of 3D modeling software, for the realization of physical objects starting from original ideas, taking advantage of geometry, mathematics and creativity.

3D3

Title: "Made in Italy – Make in Mantova"
Url: http://www.3d-archeolab.it/2016/07/come-portare-la-fabbricazione-digitale-nelle-scuole/

Description:
the course was part of an alternating school-work path focused on digital craftsmanship. It was part of the "Made in Italy - Make in Mantova" project, supported by MIUR and promoted by the "Fermi" Institute together with the Municipality, and "Alternanza e maker movement", funded by the Cariverona Foundation and the local Chamber of Commerce. It was divided into 3 sections: 3D surveying, 3D modeling, 3D printing.
During the 3D surveying phase, the students learned to make three-dimensional surveys on objects kept in Palazzo Te and at the Museo della Città in Palazzo San Sebastiano in Mantua, both through a 3D scanner and through photogrammetry. The students then learned to manipulate the three-dimensional

files obtained and to create new ones during the 3D modeling phase, and finally they learned to print in 3D, to create replicas of the surveyed objects.

Learning objectives:
awareness of the conservation and enhancement of cultural heritage

Age: 16-18

Topics: archeology, history, art history

Materials: 3D scanner, camera, photogrammetry software, 3D modeling software, 3D printer

Assessment: the experience, addressed to 40 secondary school students, was very positive, the results exceeding initial expectations. The students appreciated what they had done, according to the commitment they put into each day and the results they achieved.

3D4

Title: “weight scale”
whithin the Erasmus+ project “PrintStem”, Intellettual Output “Sperimentazioni didattiche guidate dagli alunni in logica di project work-IO3” (“Educational experiments guided by students in the logic of project work-IO3)
Url: http://www.printstemproject.eu/

Description:
the students designed the model of a two-plate weight scale, using 3D modeling software, then created the gcode by the "slicing" process, and finally 3D printed the various components that they then assembled and tested.

Learning objectives:
1) calculate area, volumes and density 2) forces 3) balance of rigid bodies 4) levers and simple machines 5) draw and recognize complex solids 6) draw and print solids in 3D

Age: 14-18

Topics: physics, geometry, technical drawing

Materials: computer, 3D modeling software, 3D printer

Assessment: the Chemistry and Science professors carried out two evaluations, one at the end of the theoretical modules and one at the end of the experimentation. There was an appreciable improvement in terms of average voting, with a reduction of the number of students with insufficient scores and a growth of the number of students with a sufficient score.

3D5

Title: "gear"
whithin the Erasmus+ project "PrintStem", Intellettual Output 4 "TEACHER-LED EDUCATIONAL EXPERIMENTATIONS FOR DEVELOPMENT OF MATHEMATICAL LITERACY COMPETENCES"
Url: http://www.printstemproject.eu/

Description:
the students studied and designed the cycloid and the epicycloid to construct the correct tooth profile of the gear. They completed three-dimensional modeling and "slicing" and finally 3D-printed the gear. The correct design of a gear requires to accurately trace the "tooth" profile so that the transmission of motion is effective, with constant torque and without play. These are traditional themes for the Mechanics course.

Learning objectives:
1) Knowing how to use the concepts of a tangent line to a circumference, of tangent or secant circles and of a circular crown for the design (technical drawing) and realization (mechanics) of a gear and for the study of circular motion (physics). 2) Knowing how to use the basic functions of goniometry for the calculation of the forces acting in a gear (mechanics and physics). 3) Implementation of the involute of the circle, of the cycloid, of the epicycle with Autocad

Age: 14-18

Topics: mathematics (trigonometry), physics, computer science (3D cad)

Materials: computer, 3D modeling software, 3D printer

Assessment: the mathematics teachers performed two evaluation tests, one at the end of the theoretical teaching units and one at the end of the experimentation.

The class in object is characterized by remarkable limits from the point of view of theoretical approach. Several students find complications in studying scientific and mathematical subjects and the interest in studying stays quite low. Regarding the practical activities, such as Technical drawing or AS, students are willing to participate and show interest in what they are doing. Most of the students who chose to study Mechanics course are mainly interested in practical activities more than theoretical activities. Following a 3D design and printing course, which requires little theory knowledge, may improve the learning of scientific and mathematical subjects.

3D6

Title: "Venturi Pipe"
whithin the Erasmus+ project "PrintStem", Intellettual Output 5 "TEACHER-LED EDUCATIONAL EXPERIMENTATIONS FOR DEVELOPMENT OF SCIENTIFIC LITERACY COMPETENCES"
Url: http://www.printstemproject.eu/

Description:
the students studied and designed a Venturi pipe to have an object capable of displaying pressure trends according to Bernulli's equation. They then completed three-dimensional modeling and "slicing" and finally printed the tube in 3D. The school where the project was carried out is in contact with companies that produce bodywork for racing cars; some of the students do internships in a company where a wind chamber can be observed. Investigating the dynamics of fluids is therefore a useful laboratory exercise.

Learning objectives:
Basic concepts of hydrodynamics. The Bernoulli equation. Basic knowledge of the geometry of space. Basic knowledge of computer science. Basic knowledge and skills in technical drawing.

Age: 14-18

Topics: physics (hydrodynamics), computer science (3D cad)

Materials: computer, 3D modeling software, 3D printer

Assessment: The Physics teacher involved in the experiment has assessed the achievement of the educational objectives by the students through standard tests. The direct observation of the students - made by each teacher who is part of the project during the experimentation - allowed to record the following additional and "cross-sectional" learning results : 1) Increased capacity in group work. 2) Increased capacity to organize work in a laboratory.

3D7

Title: 3D printed pythagorean puzzles

Url: https://docs.google.com/presentation/d/e/2PACX-1vQX7NGULjHoQdDMJGF4daX_8P85TtLagbLcef9lzGgL5-Hjghw4I9HiEuM2FDfZAcHoaUgNsX5L2svo/pub?start=false&loop=false&delayms=3000&fbclid=IwAR27YgsE2klmkIifuUZhfPBtNiWjhyddvMZ8QvhdyJNDaVIjEE8y5Tm65eI&slide=id.gc6f73a04f_0_0

Description:

the project stems from the will of the mathematics teacher and the support teacher, to involve a student suffering from phobias that do not allow him normal school attendance, in the activities of the class, to gradually accustom him to stay in school environments and with classmates. Specifically, a wooden "mathematical machine" was analyzed and reproduced by 3D printing: starting from the construction of the drawings on paper, it was then passed to the three-dimensional version with the 3D modeling software "TinkerCAD". Initially the special pupil worked in the company of only the support teacher in a dedicated classroom, demonstrating a great involvement and interest in the 3D printer, and then, moved by the desire to show his work to his companions, he entered the classroom for participate in the puzzle composition challenge.

Learning objectives:

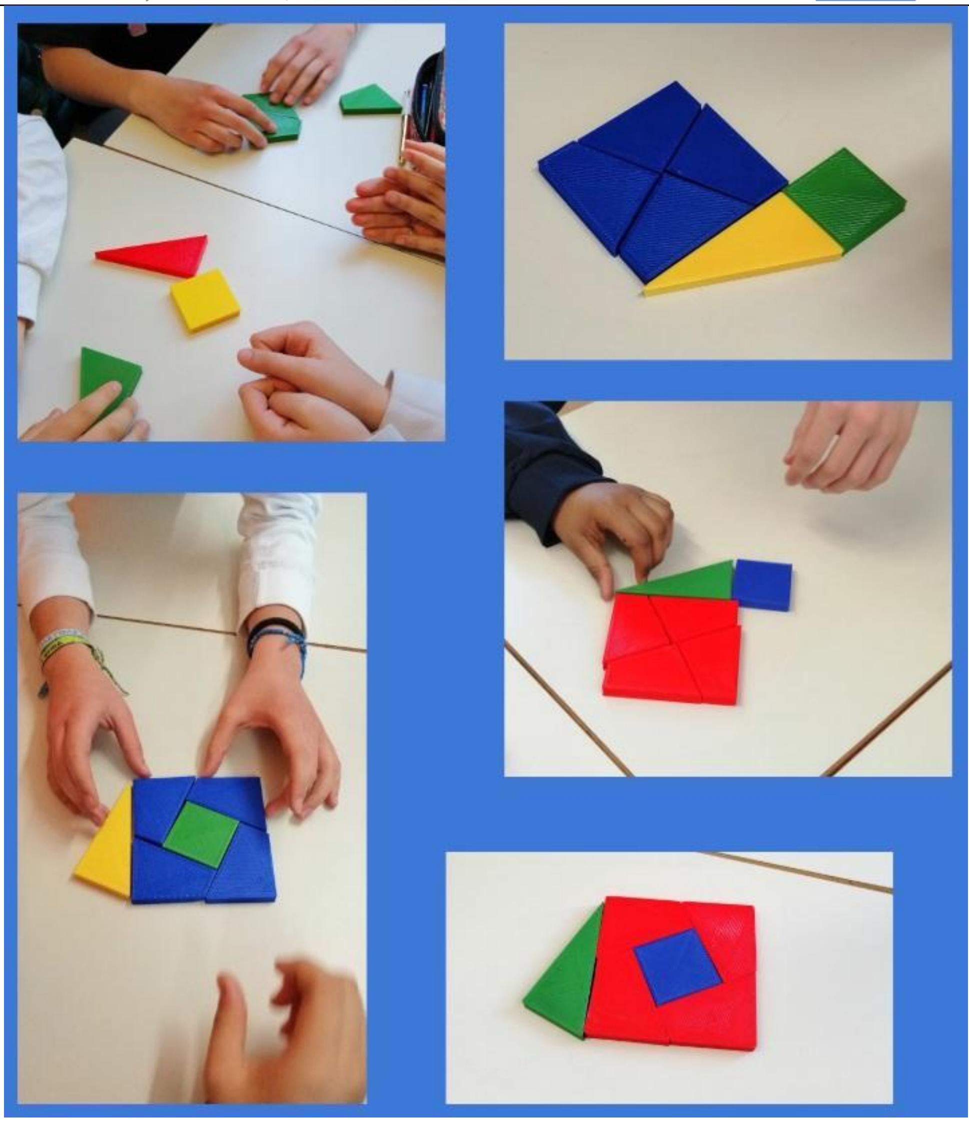
Bringing the certified student back to the classroom to carry out normal activities with the classmates; knowledge of geometry through the construction of cognitive artifacts and educational kits, using a learning-by-doing laboratory approach, through team work.

Age: 10

Topics: geometry, Pythagorean theorem

Materials: computer, 3D modeling software, 3D printer, mathematical machine

Assessment: the involved support teacher noticed a more assiduous presence of the special student during the school timetable (previously often absent) and a high interest in the use of the 3D printer and the creation of puzzles. In fact, the student was able to make about 12 kits (4 different Pythagorean puzzles) that allowed the classmates to play in teams. The student participated in the workshops / challenges for learning the Pythagorean theorem, helping and advising classmates in moments of difficulty.



3D8

Title: “Tutti a Iscol@” (project against school dropout in the Sardinia Region)

Url:

https://www.facebook.com/fablabolbia/photos/a.753533218068549/2189901964431660/?type=3&theater

http://www.iscola.it/tuttiaiscola/

Description:

The Costa Smeralda hotel team in Arzachena has reworked a typical dish of Sardinian tradition, fried ravioli, winning the first prize of "Futura Genova". In fact, they took part in the "Digital Kitchen" competition, challenging each other with the best hotels in Italy. With the use of a food-grade 3D printer, the typical Sardinian sheep milk ricotta was printed in 3D forming the honeycomb with the hexagons filled with Sardinian honey. The gastronomic composition is completed by the rose-colored white chocolate thanks to natural dyes, and the one 3D printed to reproduce the logo of the school and of the Costa Smeralda Consortium. A different destination was conceived for the violated pasta typical of seadas, which specially decorated and fried, evolved into sticks / teaspoons to taste sweet / savory.

Learning objectives:
technological innovation in food (fighting school dropouts)

Age: 16-19

Topics: pastry, cooking, 3D printing

Materials: food grade 3D printers

Assessment: the students showed a strong interest in the introduction of technology in the traditional preparation of typical dishes. The use of the 3D printer and its potential have indeed aroused a strong curiosity and stimulated creativity.

FabLab SchoolNet

Module 5.
Augmented Reality.
Theory and Practice

AR1

Title Mobile augmented reality learning objects in higher education

description Mobile augmented reality and learning objects for higher education are investigated through the mobile AR platform HP Reveal.

Hp reveal platform was selected because it was the only open marker-based AR platform found within the research for education allowing for users to follow.

age of students/type of school higher education

learning materials HP Reveal

assessment Mixed Reality and AR creation platforms like HP Reveal are becoming more easily accessible for educators and learners in higher education around the world.

AR2

Title Design and Implementation of an Augmented Reality Application with an English Learning Lesson

description an English learning lesson with a mobile-based AR application were designed and implemented in primary school level. The aim of this research is to explore the effect of well-designed lesson and learning activities with AR application. With this application students were asked to give a correct order of the 8 planets.
In the interview with the teacher, questions mainly focus on the role AR playing in the lesson and classroom.

learning objectives explore the effect of well-designed lesson and learning activities with AR application.

age of students/type of school primary school level

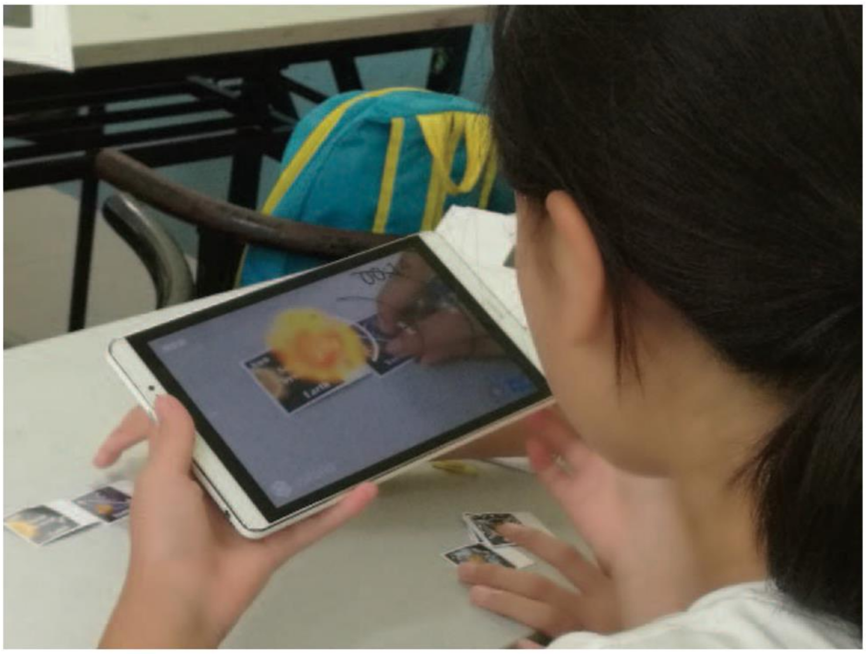
topic english learning lessons with technological topics

learning materials AR mobile application

assessment positive attitudes were demonstrated in this study
for the teacher The main question is "what is the first impression that AR gives you?", the answer was: "This technology could bring students closer to the learning content" and "In second language teaching and learning, AR could make the context more realistic in low cost, comparing to VR".

In the first group of interviewers, when talking about the inquiry-based learning activity of place planets in correct order, students said they had "communication" and "working together" with their "partners" in this process.

students' attitude towards the AR application was mostly positive. Key abilities in language learning were improved based on the analysis of face-to-face interview.



Title Towards an Augmented Reality Framework for K-12 Robotics Education

description how augmented reality (AR) can help students “see the unseen” when learning to operate and program robots.

learning objectives mprove understanding of complex dynamic models, improve motivation and interest, develop investigative skills, improve spatial skills, increase student engagement

age of students/type of school fourteen 8th graders in a private school

topic robotics education

learning materials LEGO MINDSTORMS kit, mobile AR application, Data Upload Application, IoT Cloud Application

assessment AR can help students debug their robot more easily, catalyze discussions around sensor readings that led to code fixes and reduce the “barrier to entry” for some students.

The study was conducted with fourteen 8th graders in a private school. The students were asked to program an EV3 robot to complete an obstacle course placed on a mat.

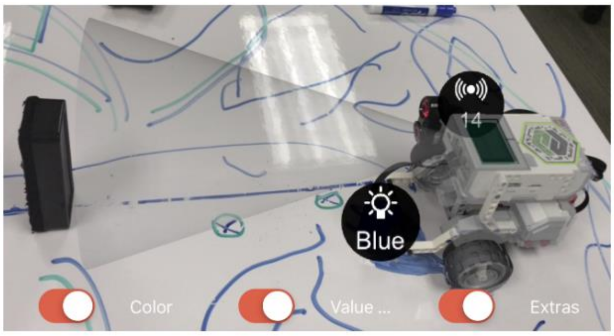


Figure 3: A view from our existing application showing two types of sensory data of the EV3 robot: 1) the sonar reading, shown as a cone and also as a number (14 cm) indicating the distance to the object; and 2) the color reading (in this case, *Blue*)

AR4

Title ScholAR: a collaborative learning experience for rural schools using Augmented Reality application

description Study of AR based application named 'ScholAR'.
ScholAR aided in developing the visualization skills of the students and realizing the existence of 3D shapes in the surrounding. The collaborative exploration of the application enhanced the performance of these students as compared to those learning by the traditional blackboard and textbook teaching method.

learning objectives enhance the spatial visualization skills of the students.

age of students/type of schoool 7th grade

topic Mathematics topic of Introduction to 3D Solids to enhance the spatial visualization skills of the students

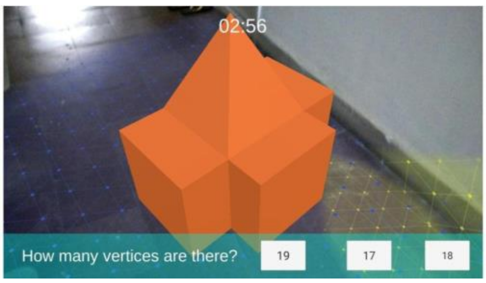
learning materials SchoolAR, mobile phone

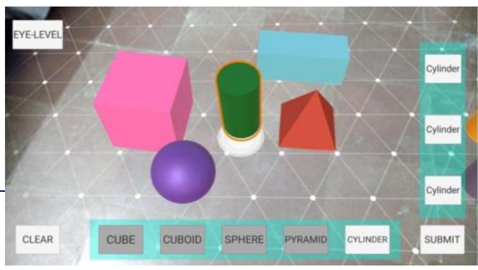
assessment The study was conducted with 32 students in two group of 16 each (experimental and control group). A day before the experiment, the teacher had been told what all topics were needed to be covered for the purpose of the experiment.

The study addresses the following Research Questions:

1. How the students interact with ScoolAR application in collaboration
2. What is the effect of collaboratively using SchoolAR in students' performance

The students were asked few questions during and post the use of the intervention, cateforized as follows: Visualization skills, perception of learning, usefulness of application, challenges in using the application, collaborative learning.





AR5

Title TECHNOLOGICAL ADVANCEMENTS IN EDUCATION 4.0

Description Review of using technological advancement in education 4.0. In particular, the technology analyzed are: 3D printing, Augmented Reality, Virtual Reality, Cloud computing, Hologram, Biometric and more. These technologies are useful to help student understand the learning contents.
"In the era of education 4.0, students are able to search millions of information in the internet, interact and collaborate with each other and so forth. Thus, policymaker need to play their role by making the use of latest technology 4.0 in teaching and learning process by educators is compulsory."

AR6

Title Effect of Augmented Reality Applications on Secondary School Students' Reading Comprehension and Learning Permanency

description analyze the effect of augmented reality (AR) applications on

reading comprehension and learning permanency

learning objectives increase in levels of reading comprehension

age of students/type of school A mixed method was used with a sample composed of 89 5th grade students (43 girls, 46 boys).

learning materials mobile phone, Aurasma

assessment that students who read using AR materials (the experimental group) perform better in reading comprehension when compared with students who read with traditional methods (the control group).
Below are the opinions of some of these students about AR applications.

S2. "It was more entertaining. It would be better to have these applications in Turkish course books as well."

S3. "It made me understand the events in the text better. It was joyous and entertaining."

S7. "The Turkish course is being taught better, this application is better than the straightforward way."

The opinions of the students on this issue are given below.

S1. "The use of the smartphone and interactive board and moving visuals in the text caught my attention."

S4. "Moving, speaking and being more like a cartoon caught my attention."

Other findings showed that most of the students believed their reading comprehension can be enhanced by reading activities with AR technologies. Some opinions of the students about this are expressed below.

S3. "Yes, it increases success. I would be even more successful if I used the application on my tablet computer or smartphone."

S4. "I think I will get better scores if we continue to cover the topics using these applications."

S6. "Learning becomes more permanent; it helps the student understand better."

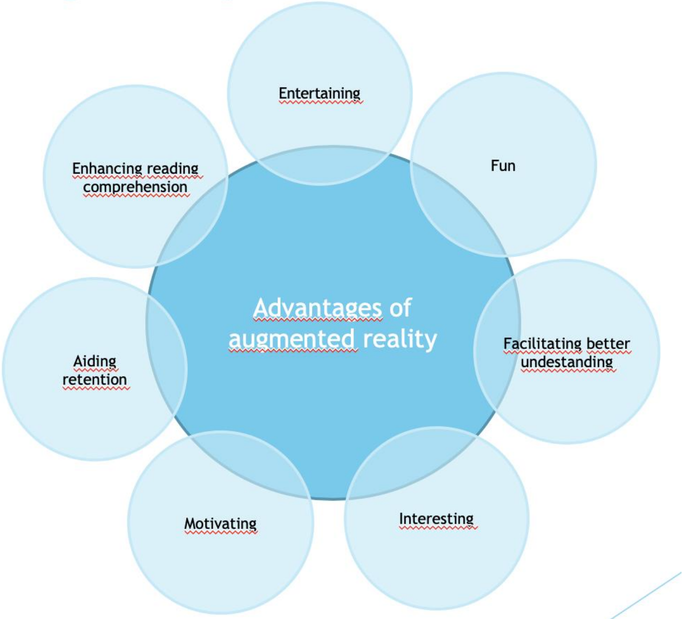
The students considered that AR technology could be used in multiple choice tests and specially to teach grammar topics in Turkish such as word meanings, relationships between words, etc. Some of the opinions of the students are given below.

S3. "It can be used in grammar. It would be good if it was used in relationship sentences such as aim-result and reason-result."

S4. "It can be used for figurative meaning, idioms, and phrases."

S5. "Idioms and phrases could be used and also, if such applications were added to question banks, it would be more educative and entertaining."

At the end of the study, it is revealed that the students in the experimental group have a positive attitude towards AR applications. They want to use this kind of application in other courses as well. They indicate satisfaction with the application and their anxiety levels are low.



AR7

Title Applying Universal Design for Learning in Augmented Reality Education Guidance for Hearing Impaired Student

description implementation of display technology used for providing information to hearing impaired students wishing to studying Information Technology (IT). In particular the objective of the mobile AR application was to provide students with a tool to understand the content without the help of teachers.

learning objectives help with learning of hearing impaired high school students

age of students/type of school higher education level

topic IT (Information technology)

learning materials HP Reveal, mobile phone

assessment Hearing impaired students are particularly interested because of mobile application usability with education guidance. the heuristic evaluation of the system was good and the students very satisfied. The possibility for an active response with the content in the AR-Book motivates students to be engaged in the learning. (Table IV and V)

TABLE IV. PARTICIPANT HEURISTIC EVALUATION OF AR EDUCATION GUIDANCE FOR HEARING IMPAIRED STUDENT

Heuristic Aspects	Average	Standard Deviation	Result
1. Visibility of system status	4.43	0.82	Good
2. Match between system and the real world	4.33	0.80	Good
3. User control and freedom	4.20	0.92	Good
4. Consistency and standard	4.33	0.84	Good
5. Error prevention	4.37	0.96	Good
6. Recognition rather than recall	4.50	0.94	Very Good
7. Flexibility and efficiency of use	4.30	0.92	Good
8. Aesthetic and minimalist design	4.27	0.91	Good
9. Help users recognize, diagnose and recover from errors	4.30	0.99	Good
10. Help and documentation	4.53	0.86	Very Good

TABLE V. RESULTS OF USERS' SATISFACTION TOWARD THE AR SYSTEM

Satisfaction	Average	Standard Deviation	Result
1. Clear explanation of content	4.53	0.68	Very Good
2. Easy to follow content	4.40	0.67	Good
3. Easy-to-understand translated sign language	4.90	0.31	Very Good
4. Clear texts and good quality images and videos	4.73	0.45	Very Good
5. Appropriate language use	4.53	0.63	Very Good
6. Techniques used in the Application	4.50	0.57	Very Good
7. Good layout of content	4.47	0.57	Good
8. Easy usage and navigation	4.37	0.67	Good
9. User satisfaction	4.40	0.77	Good
10. Benefits of using the system	4.67	0.61	Very Good

AR8

Title Augmenting the learning experience in Primary and Secondary school education: A systematic review of recent trends in augmented reality gamebased learning

description This study reports a systematic review of the literature on AR approaches in compulsory education considering the advantages, disadvantages, instructional affordances and/or effectiveness of AR across various Primary and Secondary education subjects.

learning objectives This review aims to lay the groundwork for educators, technology developers, and other stakeholders involved in the development of literacy programmes for young children by offering new insights with effective advice and suggestions on how to increase student motivation and improve learning outcomes and the learning experience by incorporating ARGBL into their teaching.

age of students/type of school primary and secondary school

assessment The goals of this study are as follows:

a. To provide an overview of the educational use of ARGBL in Primary and Secondary education, including the kinds of devices used, the digital resources and employed software, what subjects are making use of AR technology, where courses using AR take place, and how the devices are used for teaching and learning.

b. To present the overall effect on students' learning achievements when ARGBL is integrated into Primary and Secondary education.

c. To synthesise the potential teaching and learning advantages and disadvantages of implementing ARGBL within different instructional contexts, based on analysis of relevant articles.

The educational potential of AR technology is significant, because of the benefits that influence the students' cognitive acceleration, the increase to their self-management, and the enhancement to their engagement in practice-based activities. Specifically, ARGBL can be useful for educators to recognise the educational potential and affordances in their different disciplines. Marker-based AR is the most commonly used type of AR in Primary and Secondary education, followed closely by location-based AR, owing to the availability of sensors in mobile devices such as gyroscopes, accelerometers.

Primary education	Number of studies	Percentage (%)
Marker-based AR	7	50.0
Markerless AR	3	21.4
Location-based AR	3	21.4
Not specified in the study	1	7.2
Secondary education	**Number of studies**	**Percentage (%)**
Marker-based AR	5	71.4
Markerless AR	1	14.3
Location-based AR	1	14.3

Primary education	Number of studies	Percentage (%)
Tablets	5	35.7
Smartphones	4	28.5
Computer (laptop/desktop) combined with a video camera	4	28.5
Motion sensing input devices (e.g., Microsoft Kinect)	1	7.3
Secondary education	**Number of studies**	**Percentage (%)**
Tablets	0	0.0
Smartphones	3	42.9
Computer (laptop/desktop) combined with a video camera	4	57.1
Motion sensing input devices (e.g., Microsoft Kinect)	0	0.0

Title Augmented Reality for Enhancing Life Science Education

description This paper will describe the results of a consultation on the use of digital visualisation technologies in the teaching of life science subjects and the creation and testing of an AR application to aid in the teaching of metabolism, specifically linked to glucose and insulin signalling.

learning objectives AR applications that aim to transform the learning space into one that is highly interactive

topic Life science education

learning materials App on android phone and windows tablet

age of students/type of school 19-24 years of age

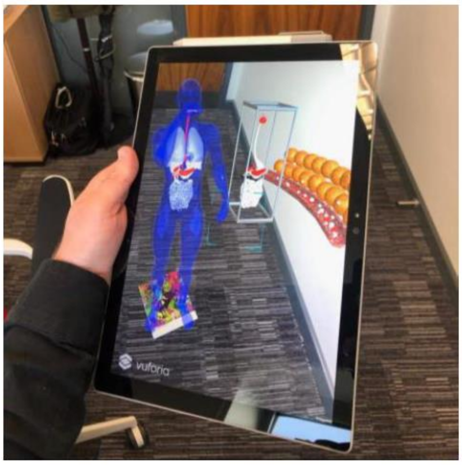


Figure 8. App Functioning on Windows Tablet

assessment The present study was conducted in the School of Medicine, Medical Sciences and Nutrition at the University of Aberdeen. Ninety participants were self-selected by completing a survey as part of a second year undergraduate biochemistry course that forms part of the core curriculum for most life science degree programmes. Of the ninety questionnaire participants, eight were randomly selected to take part in a focus group and seven volunteered to test an AR application linked to the teaching of metabolism.

The following questions, which emerged from the questionnaire data, were used to encourage discussion: 1. Do you have difficulty visualising and learning abstract concepts? 2. How do you currently learn these difficult topics? 3. What would be the best use of gamification to teach lecture topics?

In summary, AR was favoured over VR and the participants would prefer any AR content to be used in a tutorial rather than lectures so that information from lectures could be consolidated rather than being taught for the first time.

AR10 – pag 19 AREdu2018ProcBook

Title Use of Augmented Reality in Chemistry Education

description This article analyze the current trends in the use of the augmented reality in the chemistry education to identify the promising areas for the introduction of AR-technologies to support the chemistry education in Ukrainian educational institutions.

topic chemistry education

learning materials

Name of tools	Description of features
Arloon Chemistry [1]	3D-modelling of the process of molecular or crystal creation from individual atoms
Augmented Chemical Reactions [14]	3D-visualization of molecules, their spatial dynamics and interaction, possibility to form molecules from individual fragments
Augment [15]	3D-visialization of molecules and crystal lattices
Study Marvel-Chemistry AR [29]	3D-illustrations and models in special printed educational textbooks and publications on chemistry
AR VR Molecules Editor Free [33]	3D-visualization of molecules, organic and inorganic compounds in different forms (stick, ball-and-stick, scale models etc.)
Atomic Structure AR Learning Gear	Dynamic 3D-visualization of atom models, electron clouds, studies which have led to the discovery of electrons, atom structure etc.

Name of tools	Description of features
[12]	
Dáskalos Chemistry [7]	Visualization of the atom structure of all chemical elements with the possibility to look through additional data
HTMoL – AR plugin [28]	3D-modelling of molecular structures with the possibility to use the computational characteristics of molecules and semiautomatic animation for reactions through linear interpolation of atom coordinated between gradual computational stages of reactions
Elements4D [6]	Availability of additional information and images of appearance of substances, possibility to model chemical reactions between them
EVToolbox [8]	Russian-language resource of modelling interactions between atoms with the creation of molecules and structure of molecules and their interaction with each other
AR Learning [31]	Modelling of certain chemical reactions and physical and chemical processes
MEL Chemistry [17]	3D-modelling and molecular animation, structure of crystal lattices, detection of substances according to the special markers

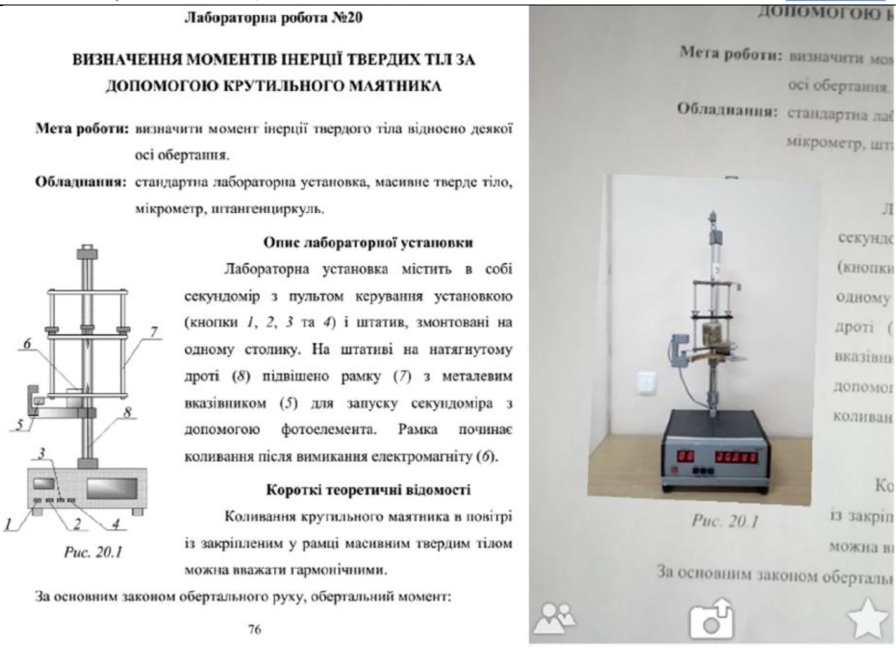
1. artificial markers (images on the plane something similar to QR-codes or other images);
2. chemical symbols;
3. real objects.

AR11 – pag. 37 AREdu2018ProcBook

Title Augmented Reality Tools in Physics Training at Higher Technical Educational Institutions

description The research is to solve the problems of determining the role and place of the technology in the educational process and its possible application to physics training.

Introduction of the augmented reality technology in the training process at higher technical educational institutions increases learning efficiency, facilitates students' training and cognitive activities, improves the quality of knowledge acquisition, provokes interest in a subject, promotes development of research skills and a future specialist's competent personality.
When pointing a smartphone or tablet camera at a picture-marker, a mobile device starts scanning it. On the screen, there appears a video of a lecturer demonstrating a laboratory installation, its basic components and commenting on the experiment procedure. It helps visualize students' step-by-step actions, indicate peculiarities of each work, consider them and save time. AR application to physics workshops facilitates students' understanding of drawings, instructions as it supplements printed information.



Лабораторна робота №20

ВИЗНАЧЕННЯ МОМЕНТІВ ІНЕРЦІЇ ТВЕРДИХ ТІЛ ЗА ДОПОМОГОЮ КРУТИЛЬНОГО МАЯТНИКА

Мета роботи: визначити момент інерції твердого тіла відносно деякої осі обертання.

Обладнання: стандартна лабораторна установка, масивне тверде тіло, мікрометр, штангенциркуль.

Опис лабораторної установки

Лабораторна установка містить в собі секундомір з пультом керування установкою (кнопки *1*, *2*, *3* та *4*) і штатив, змонтовані на одному столику. На штативі на натягнутому дроті (*8*) підвішено рамку (*7*) з металевим вказівником (*5*) для запуску секундоміра з допомогою фотоелемента. Рамка починає коливання після вимикання електромагніту (*6*).

Рис. 20.1

Короткі теоретичні відомості

Коливання крутильного маятника в повітрі із закріпленим у рамці масивним твердим тілом можна вважати гармонічними.

За основним законом обертального руху, обертальний момент:

76

learning objectives Teaching physics to students of higher technical educational institutions. The objective is to solve the problems of determining the role and place of the technology in the educational process and its possible application to physics training.

topic Physics

age of students/type of school undergraduates

learning materials software tool Aurasma (HP Reveal)

assessment Skills of experimenting and data analysis are developed during laboratory practicums when a student conducts experiments independently. At the initial stage of the laboratory practicum, a lecturer should make the material interesting as in interest situations,

students’ fatigue falls, while efficiency of training rises [10]. Introduction of the augmented reality technology as a visualization tools of training material presentation is an important condition of learning efficiency increase at higher educational institutions. Students with visual thinking have difficulty in understanding and mastering training material as they are unable to comprehend and study a phenomenon without visualizing it. Students with theoretical thinking, who are able to acquire formalized knowledge, can use mobile learning tools as an additional mean for developing their visual thinking and focus.

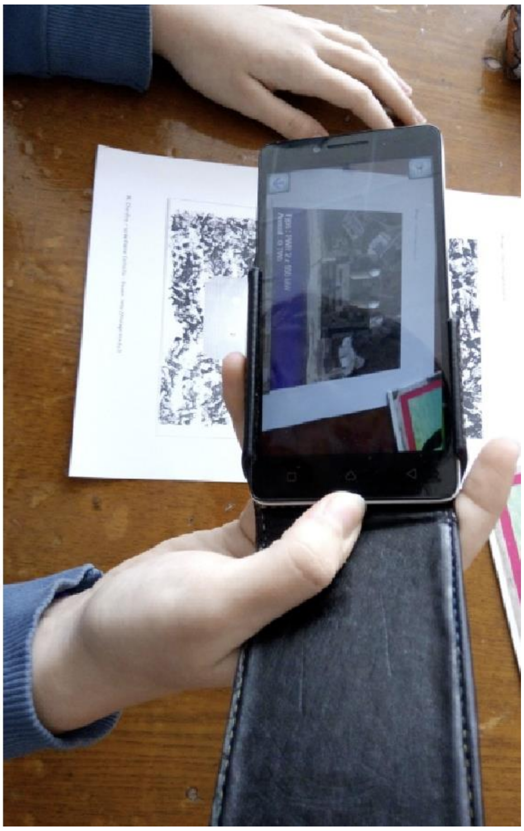
Students, who were offered to use the AR technology, got interested in applying it to performing laboratory works as an additional learning tools and liked the idea of visualizing training material through a mobile application.

AR12 – pag. 57 AREdu2018ProcBook

Title Implementation of Gamification and Elements of Augmented Reality During the Binary Lessons in a Secondary School

description The object of the research is the process of teaching Physics and English (binary lessons) in a secondary school through the use of gamification elements and augmented reality.
After the announcing of the theme of the lesson students are encouraged to explain the

task encoded using QR codes and thus split them into teams. QR codes can be used in game quests to offer game tasks at one or more stages of the corresponding activities, in educational crossword puzzles. During the main part of the lesson students carry out experimental tasks: one group of students carries out experimental tasks with the help of devices, and the other group of students is encouraged to watch the video after scanning the QR-code.



Funded by the Erasmus+ Programme of the European Union

learning objectives The purpose of the research is to consider the possibilities of gamification and elements of augmented reality in the secondary school during the binary lessons in Physics and English

topic Physics and English (binary lessons)

age of students/type of school 7th grade (secondary school)

assessment Binary lessons are an effective means of increasing the motivation of studying

natural sciences as they create conditions for the practical application of knowledge; develop students' skills in self-education, since a significant part of the training is carried out by students on their own and after classes.

AR13 – pag. 70 AREdu2018ProcBook

Title The Potential of Using Google Expeditions and Google Lens Tools under STEM-education in Ukraine

description The purpose of the article is to analyze the possibility of implementing interactive methods of augmented reality in the educational system of Ukraine, through the use of Google Expeditions and Google Lens. Google Expedition AR is Google main instrument based on AR which imposes virtual objects on the reality fixed by phone (table) camera.

Fig. 2. Example of using AR in education

In the contrast of widely used and well-known Google Expeditions AR's applications, there exist Google Lens which is innovated of education. Lens recognizes the image and its show the relevant information about it.

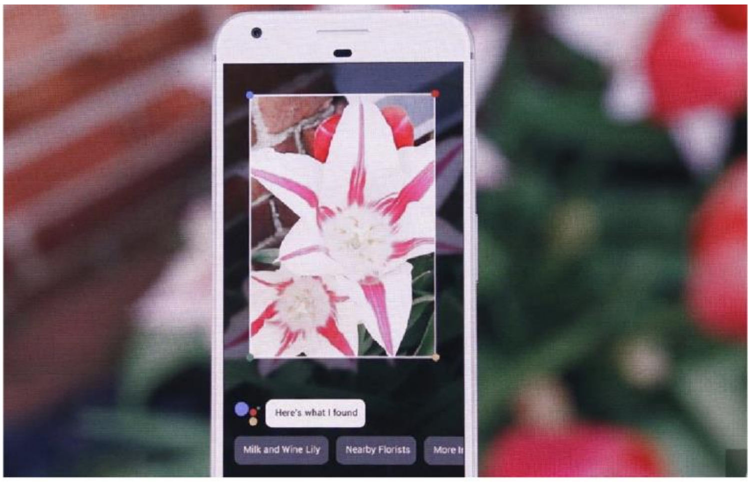


Fig. 3. The example of Google Lens using in the biological research

Lens and Expedition can improve the motivation level of students due to its interactivity.

	Google Expedition	**Google Lens**
Motivation	Due to IT using, and it's interactivity	Provided by possibility to use personal phones any time to research
Interactivity	Provided by possibility of the Google Expedition to visualize natural phenomena	Interaction with any objects
Knowledge increasing	Due to the information visualization	Due to the possibility of research any object any time
Other advantages	Simplification of the linking between other people and interact with their surroundings, improving of the teamwork, introduction of facilitator's role, possibility to study of the low-spatial ability learners, size understanding, better memorizing, possibility to simulate the dangerous situations, providing STEM-education	

	Google Expedition	**Google Lens**
Abstract	AR instrument	Image analyzing system
Approaches in education	Physics, chemistry, biology, geography, history, architecture	Biology, history, architecture, mineralogy, geology, engineering
Pedagogical aspects	Lack of teachers awareness of this instruments, lack of the methodical achievements and there absence of Ministry of science and education recommendation about it	
Technical problems	There is no official Google office in Ukraine (or it's weak communication) and lack of equipment	High equipment cost of the Lens supported stuff, there some mistakes of under working
Other problems	There is necessary to be careful with AR-devices due possibility of damage the device during which might damage electronic components, problems GPS errors effect on the accurate of markerless AR programs	

Funded by the Erasmus+ Programme of the European Union

topic STEAM education

age of students/type of school primary and secondary school

learning materials Google Expeditions, Google Lens, smartphone, Google Cardboard