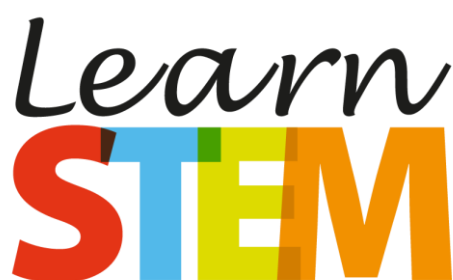# Learn STEM
Innovative STEM learning in schools

Inquiry Learning Package
for Innovative STEM Learning and Teaching

http://www.learn-STEM.org

Learn STEM

Inquiry Learning Package for Innovative STEM Learning & Teaching

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Learn STEM

Inquiry Learning Package for Innovative STEM Learning & Teaching

The **Inquiry Learning Package** provides tools and examples for Innovative STEM Learning and Teaching and in particular for the application of **Learn STEM**.

Learn STEM is the **Pedagogical Model for Innovative STEM Learning and Teaching**. It comprises a general framework for improving learning and teaching of Science, Technology, Engineering and Mathematics (STEM) in secondary schools. It has been developed by nine partners from six European countries (The Netherlands, Belgium, Germany, Italy, Lithuania and Portugal), including experts with professional background in the field of teaching STEM, secondary schools, research, vocational education institutions and developers with technical knowledge and expertise.

Learn STEM provides teachers not only with general guidelines, but also with tools for their practical school education in STEM. This refers particularly to the Inquiry Learning Package and training modules.
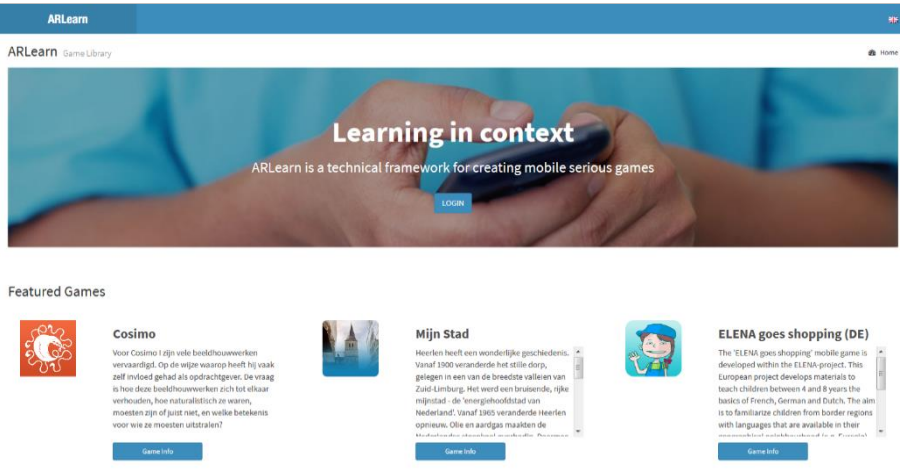
Consequently, the following examples and tools have been selected to support teachers in implementing practical STEM exercises which follow the principles of **Learn STEM**.

They incorporate the following STEM subjects:

Informatics (Robotics and Internet of Things):   Examples 1–8

Physics: Examples 9–10

Biology and Chemistry: Examples 11–12

The **Learn STEM** Inquiry Learning Package for Innovative STEM Learning & Teaching is online available at: www.Learn-STEM.org/Tools

The **Learn STEM** Pedagogical Model for Innovative STEM Learning & Teaching is online available at: www.Learn-STEM.org/Model

|	Example 1
Title	ARLearn
Company or website	https://streetlearn.appspot.com/ (open source software for free)
Image	
Description	ARLearn is a platform for creating and playing mobile serious games providing additional videos and instructions. It consists of: 1. An authoring environment accessible at https://streetlearn.appspot.com/, 2. An app, available through the google play store. ARLearn is an open source software, it is available for free and adjustable to your needs.
Age range	All ages
Language	English, Dutch, German
Principles	ARLearn follows and supports all five principles of the Learn STEM Pedagogical Model: 1. **Complex:** ARLearn allows teachers to create games at any complexity, 2. **Process-oriented:** Pupils have to solve games by themselves or through team work, 3. **Holistic:** ARLearn facilitates learner-centered exploration, 4. **Practical:** ARLearn can be combined with any location and tasks from the environment, 5. **Social:** ARLearn requires collaboration of learners for solving these defined games.
Lesson ideas	The authoring environment enables two processes. 1. It enables the author to **design** and **implement** games. 2. It enables users to **deploy** games to a mobile device. This means that, when a user creates a game with the authoring environment, the game will not render visible on the mobile app. In order for a game to become visible on the mobile app, a run must be created first and players should be defined. After adding players to a run, players will see the game appearing on the ARLearn Android player.

Playing a game

Playing a game on your mobile device assumes that both, a game and a run, were created and that your account was added to the run. When ARLearn is installed on the mobile device, it will show the following screen:
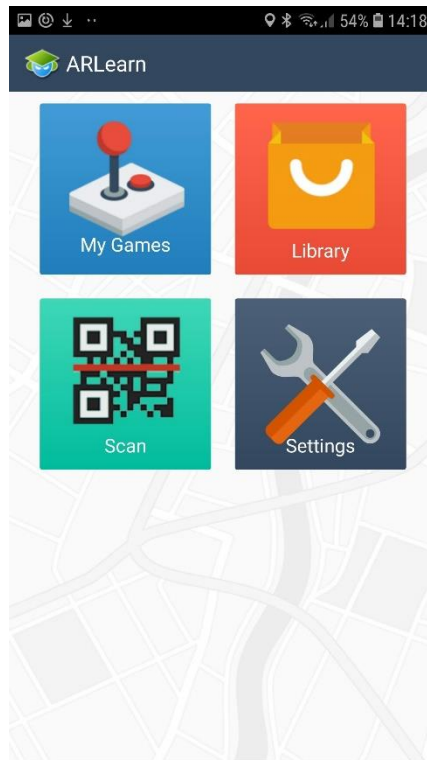

Within this screen only My Games ("Mijn spellen") and Settings ("Instellingen") are relevant.

When tapping on the option "My Games", you will - depending on whether you are logged in- see either your list of playable games or an authentication screen. Note that the scan button will not work on newer devices.
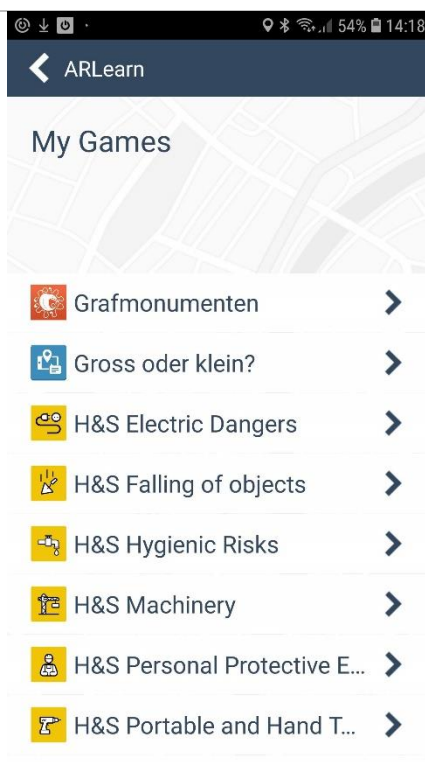
Users often struggle with an empty list. No games in this list means that your account has not been added as a player to a game run yet. After opening a game, you should either see a list of messages or a map displaying interactive markers.
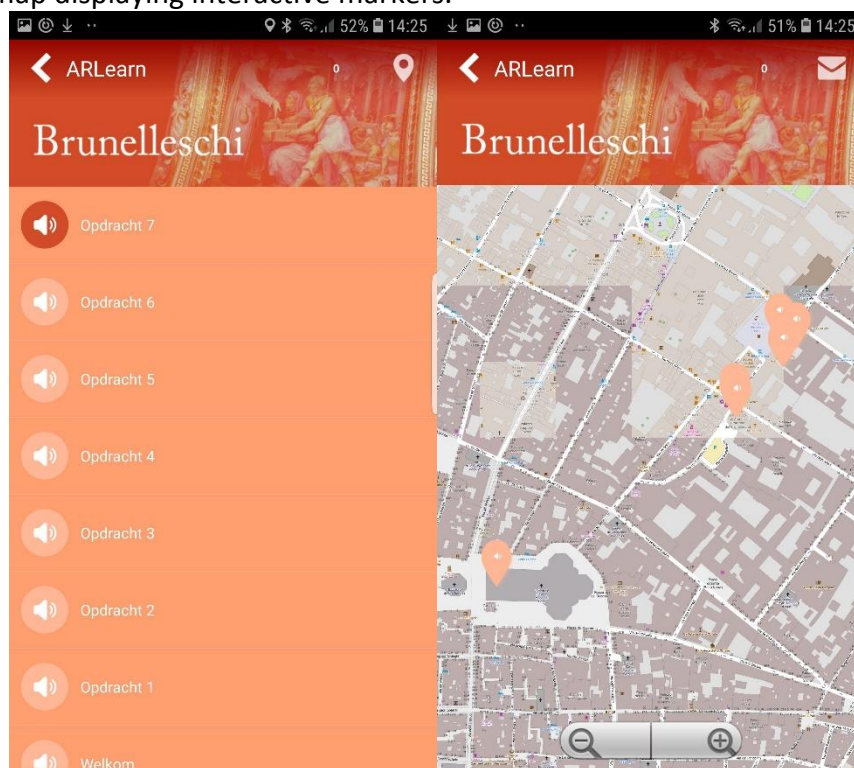
Opening a message in either of both views, typically leads to a multimedia message like:

Various kinds of messages are possible, including video, audio, multiple choice or rich text messages.

Creating games and runs

ARLearn defines a game as a blueprint for mobile activity. A game specifies messages that appear either in a message list or on a map. Various kinds of messages are possible: Video, Audio, QR scanners, questions, etc.

Appear and remove conditions define the logic for a message to appear or disappear from the message list or map. One can e.g. specify that a message will only appear when a user has:

- specified a correct multiple choice answer,
- scanned a QR label with a given scanner,
- finished listening to an audio file,
- ...

A run binds a game to a group of players. All actions that a user or group of players execute within a run are only visible for the players of a run and for the creator of the run. These actions include answers given to questions and media that is recorded. A run makes it possible to replay a game design with different groups of players.

At the following two links more details are found on how to create a game and a run:

- https://streetlearn.appspot.com/#/documentation/tutorial/game
- https://streetlearn.appspot.com/#/documentation/tutorial/run
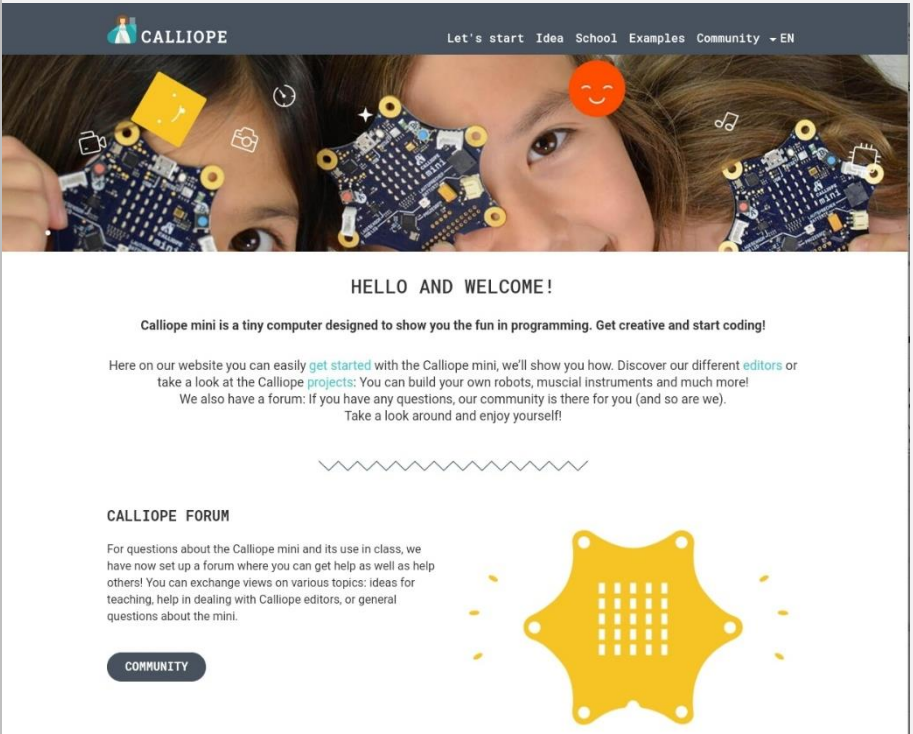
	Example 2
Title	BIPARCOURS
Company or website	https://biparcours.de/ (open source software for free)
Image	
Description	BIPARCOURS is an online platform and service for creating and playing portable scavenger hunts and games. BIPARCOURS consists of: 1. A scavenger hunt creator, 2. A learning tool as player. BIPARCOURS is freely available for Android and iOS devices and requires registration only. You can find videos and instructions on the website: https://biparcours.de/#video1 https://biparcours.de/#video2
Age range	All ages

Language	German, but supports any language
Principles	BIPARCOURS follows and supports all five principles of the Learn STEM Pedagogical Model: 1. **Complex**: BIPARCOURS allows teachers to create scavenger hunts at any complexity, 2. **Process-oriented**: Learners may solve courses by themselves or in teams, 3. **Holistic**: BIPARCOURS facilitates learner-centred exploration, 4. **Practical**: BIPARCOURS can be combined with any location and tasks from the environment, 5. **Social**: BIPARCOURS requires collaboration of learners for solving the defined courses.
Lesson ideas	BIPARCOURS is an online service for learning inside and outside of schools offered by Bildungspartner NRW. Schools and institutions can create quizzes, tasks, city and nature guides on various topics. Creating these scavenger hunts is simple and intuitive and can be done without any prior knowledge or training. You can create your own scavenger hunts connecting indoor and outdoor locations with media content, quizzes and tasks. After publication, other registered members (teachers and pupils) may use your scavenger hunt on their phone or tablet.

	Example 3
Title	Calliope - A tiny computer designed to show you the fun in programming. Get creative and start coding!
Company or website	www.calliope.cc
Image	
Description	Calliope mini is a tiny computer designed to show you the fun in programming. Get creative and start coding! With a little practice and the right software, the Calliope mini can become an instrument, a calculator, a weather station or a disco ball. They continuously collecting exciting experiments and lessons and are looking forward to many new ideas for personal Calliope projects. To start, there is no pre-knowledge or skills needed. When the projects get more challenging, the Calliope can connect to external sensors and output. Instead of using program blocks, coding can be done in javascript or NEPO. To program Calliope, you use different editors, depending on your experience in programming: **CALLIOPE MINI EDITOR** This is the easiest way to program your mini. Using the Calliope mini editor you can transfer your own images and texts to your mini. https://miniedit.calliope.cc/ **MAKECODE** Using the MakeCode editor, you can control your Calliope mini in various ways. Either you arrange program blocks or you use JavaScript.

	https://makecode.calliope.cc/ **OPEN ROBERTA LAB®** With Open Roberta programming is a piece of cake. 'Open Roberta Lab' allows even newbies to program intuitively with the graphical programming language NEPO. The open-source platform is based on the long-standing knowledge of the Fraunhofer initiative 'Roberta - Learning with robots'. https://lab.open-roberta.org/#loadSystem&&calliope2017 Calliope mini and additional hardware can be purchased at: https://calliope.cc/shops.
Age range	8 and older
Language	Several including German, English, French and Dutch
Principles	Calliope is designed to support computational thinking and design thinking. Learners can design and create a real product related to the five principles of the Learn STEM Pedagogical Model: 1. **Complex**: Calliope allows teachers to create at any complexity, 2. **Process-oriented**: Learners may program by themselves or in team, 3. **Holistic**: Calliope facilitates learner-centered exploration, 4. **Practical**: Calliope can be combined with any location and tasks from the environment, 5. **Social**: Calliope requires collaboration of learners for solving difficult tasks.
Lesson ideas	The website provides different projects, grouped by minimum age of learners, complexity, subject and duration. You can find them on: https://calliope.cc/en/projects The projects are very well documented with screenshots and background information.

	Example 4
Title	PLICKERS
Company or website	https://www.plickers.com
Image	
Description	Plickers is an instant classroom-polling app that lets teachers scan paper cards for leaners responses. It is an excellent tool to support classes and motivate learners by actively engaging in Internet of Things. Teachers can create an account and design lessons with questions. Using individual names or simply numbers, teachers may print cards for each learner comprising the chosen identification as well as the letters from A to D. After printing the cards, teacher can design questions for their students. Multiple lessons can be saved on one account and be reused. Teachers will have the option to give multiple choice answers providing at least four possible options (A-D), for instance: "*How many official languages does the European Union have?*" which allows only one correct answer or, for instance: "*What do you think about IoT?*" which allows learners to choose and give their opinion. To answer a question, learners must hold up one of their cards marked from A to D. Teachers can then scan all the answers with their smart phone and analyse results. Technical requirements are a mobile phone and a computer (connected to a beamer) with internet connection. The App can be downloaded for free on Android or iOS devices. Find the Getting started guide on https://help.plickers.com/hc/en-us/articles/360008947934-Getting-Started-Guide 1.1 **Further resources:** help.plickers.com help@plickers.com Twitter: @plickers
Age range	8 and older

Language	English but questions can be asked in any language
Principles	Plickers follows and supports all five principles of the Learn STEM Pedagogical Model 1. **Complex**: Plickers allows teachers to create games at any complexity, 2. **Process-oriented**: Learners have to solve 'games' by themselves by giving correct answers/or opinions, 3. **Holistic**: Plickers facilitates learner-centered exploration, with open questions, 4. **Practical**: Plickers is very practical including the leaner as an element of the 'game', 5. **Social**: Plickers can require collaboration of learners to solve questions.

Lesson ideas	This tool can be used in many different ways.
	
	Idea 1: Correct answers
	
	In this example, the teacher will use Plickers to assess their knowledge progress at the end of class.
	For example, if the class subject is the European Union (EU), one type of question may be: "*How many people live in the EU?*"
	    A. 108 million
	    B. 208 million
	    C. 308 million
	    D. 408 million
	
	Afterwards teachers scan all cards learners have chosen as answers using their mobile phone. The correct answer can then be projected on the screen (answer D).
	
	Idea 2: Open questions
	
	Plickers enables us to get leaners personal opinions on topics. This can help teachers to launch a new thematic/debate, for example "*What do you think about the social networks?*"
	    A. I love it.
	    B. I don't use it.
	    C. It's a good way getting to know more people.
	    D. It's too dangerous.

	Example 5
Title	robomindacademy
Company or website	https://www.robomindacademy.com/robomind/home
Image	
Description	Robomind Academy is an online platform to get into programming at home or school. Robomind Academy consists of: - A virtual mentor which validates solutions, helps with problems and guides learners through the course, - Teacher support with real-time dashboard to monitor progress of the class, - Competition screen to run programming contests with the whole class or school. Robomind Academy is available as free ware but also offers paid courses.
Age range	8 and older
Language	English and Dutch
Principles	Robomind Academy follows and supports all five principles of the Learn STEM Pedagogical Model: 1. **Complex**: Allows teachers to create lesson plans of any complexity, 2. **Process-oriented**: Leaners practice problem solving and computational thinking, the 21st century skills, 3. **Holistic**: Learners demonstrate originality and creativity at work and understand the real-world limits to adopting new ideas, 4. **Practical**: Robomind Academy can be done at any location, by teachers and learners, 5. **Social**: Robomind Academy requires collaborative work among the learners.
Lesson ideas	Learners can engage in the first steps of coding by seeing their code outcome in a virtual environment where the robot moves: Our robot, can move and look around, pick up beacons and paint the floor.
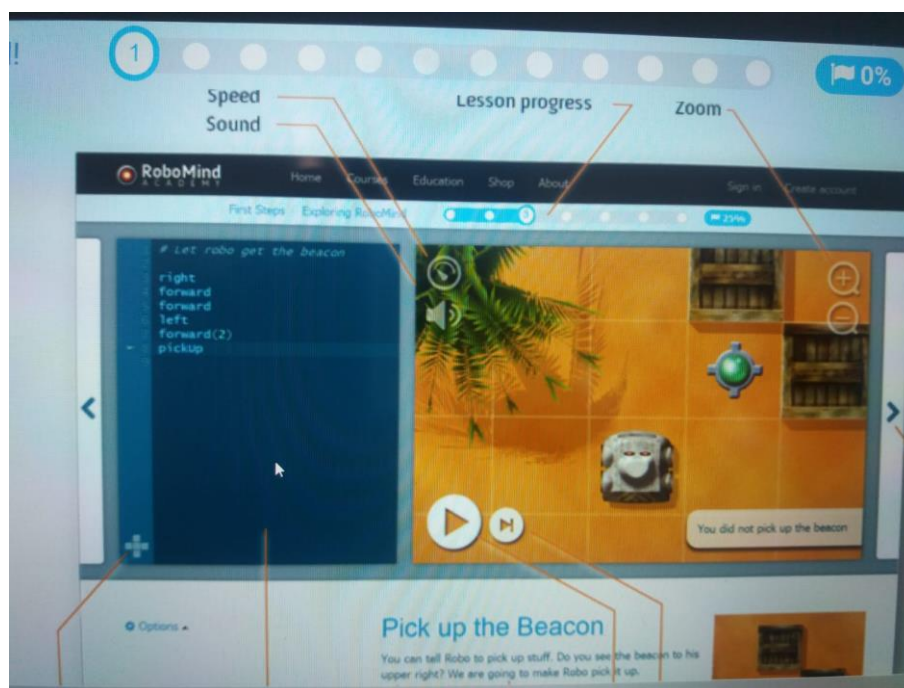
The robot can be placed onto different maps (worlds). You can look around by dragging the map with the mouse or touch. You can change the scale by using the zoom buttons, use the mouse-scrolling wheel or click on the zoom button.

A solution is a script (program) created in this text field. Scripts are written instructions (commands), normally executed from left to right, top to bottom. Use the remote control to see what instructions you can use or see the documentation below.

To run your script, click the play button, and see if it solves the described problem. If not, you'll probably get a hint.

This platfform also assist to create loops, define instructions, explain conditions, logical expressions and procedures.

Time-saving curriculum and self-paced courses with automatic validation and hints provide flexibility for 1-on-1 attention. The courses are self-contained so that the teacher can concentrate on mentoring the learner.

Supports general curriculum standards in many countries.

	Example 6
Title	**Arduino**
Company or website	www.arduino.cc
Image	
Description	Arduino Education offers solutions for the classroom, kits, bundles and boards with learning paths for individual and collaborative educational approaches. Learners explore the microcontroller Arduino in a hands-on, constructive way as they work through the kits and explore the creative capabilities of each board. Users of Arduino can have different educational background in electronics, from beginner to expert. Educational institutions use Arduino as a resource to assist in educating their learners on a wide variety of topics, using several methods. **Develop:** Arduino is widely adopted by post-secondary education (e.g., universities, colleges, research institutes) in the fields of engineering, Internet of Things, robotics, art, and design. **Teach and Learn:** Many secondary schools use Arduino in innovative programs for cross-curriculum studies. **Play:** Primary schools use toys embedded with Arduino technology to introduce physical learning, logic, building skills and problem solving. The software is free, the hardware device is not free. You can find an overview of the hardware and costs here: https://store.arduino.cc
Age range	11 and older
Language	English, but there are also spinoffs in different languages

Principles	Arduino Academy follows and supports all five principles of the Learn STEM Pedagogical Model: 1. **Complex**: Allows teachers to create challenges at any complexity, 2. **Process-oriented**: Leaners practice problem solving and explore programming by themselves, 3. **Holistic**: Facilitates learner-centered exploration, 4. **Practical**: Can be combined with any location and tasks from the environment, 5. **Social**: Can requires collaboration of learners for solving tasks.
Lesson ideas	The website provides examples and tutorials: https://www.arduino.cc/en/Guide/HomePage You can filter the projects in the Arduino project Hub by categories (like audio & sound, flying things, home & automation, sensors, environment, motors, etc.).

	Example 7
Title	**Tiles IoT Toolkit**
Company or website	http://tilestoolkit.io/
Image	Play with **Tiles IoT Toolkit** Generate ideas and make great IoT inventions Zero experience required Bike — An object that integrates with your bike or is brought along with the bike, like a helmet or a lock. Objects 1-2 Lift — The user lifts the object from a static surface. Inputs 1 - 2 Vibrate — The object starts vibrating. Outputs 0 - 6
Description	This toolkit is the visible output of a research project established by the Norwegian University of Science and Technology. Core resources are 'Tiles IoT Cards' which contain a description of IoT components and other components to be used for designing/developing meaningful learning experiences. 'Tiles Workshop' provides training in the fundamentals of IoT and how to combine 'Tiles IoT Cards' with design thinking techniques in order to ideate IoT-based solutions to specific problems. The activities shared are learner-driven and quite challenging. The advantages are the attractive design of 'Tiles IoT Cards', as well as the universal connection with design thinking techniques. There is some documentation and examples that can be used for developing lesson plans. Most of the educational resources are available for free. 'Tiles IoT Cards' can be downloaded in accordance to Creative Commons BY-SA license. The website also provides a link to purchase hardware and firmware.
Age range	12 and older
Language	English
Principles	'Tiles IoT Toolkit' is compliant with the five principles of the Learn STEM Pedagogical Model: 1. **Complex**: The diverse challenges proposed allow teachers to design activities of increasing complexity, 2. **Process-oriented**: Activities proposed are learner-driven, 3. **Holistic**: Its implementation conveys a learner-centred exploration, 4. **Practical**: There is a rich context beyond, allowing users to explore possibilities and be creative, 5. **Social**: 'Tiles IoT Toolkit' proposes several activities linked to the surrounding environment and to everyday objects/things, requiring collaboration between peers.

Lesson ideas	The 'Tiles IoT Cards' are split into six different categories: things, data, channels, human actions, feedback, missions and criteria. Learners are proposed to address a specific problem by following a human-centered approach. The purpose is to follow an ideation process in order to identify a useful solution by means of using design thinking techniques.
	The journey starts with a set of (problem) scenarios and personas given to participants to choose from. Participants are in turn asked to choose and combine things, data, human action and feedback relevant to the selected scenario. Drawing on those cards, participants develop an initial concept and create sketches/drafts. Next, participants are asked to challenge their own ideas getting inspired by missions cards. A refined idea is now visualised on the idea generator board. Participants are then asked to collaboratively reflect and improve their concepts using criteria cards and to prepare an elevator pitch to present their concept to the audience (other participants, mentors, investors).
	Objectives: • Introducing Internet of Things and design thinking, • Explaining the different roles and perspectives inherent to problem-solving, • Developing various soft skills (adaptability, creativity, communication, etc.), • Exploring the role of IoT-based technologies to deal with real problems.

	Example 8
Title	**Robotics with LEGO EV3 MindStorms robots**
Company or website	https://education.lego.com/en-us/middle-school/intro/mindstorms-ev3 https://makecode.mindstorms.com/
Image	
Description	LEGO®MINDSTORMS Education EV3 is a hands-on, cross-curricular STEM solution that engages learners by providing the resources to design, build and program their creations while helping them develop essential 21st century skills such as creativity, critical thinking, collaboration, and communication. The education set contains all necessary components to build simple robots with up to four motors and four sensors (colour, ultrasound, touch, gyroscope). On the first website (LEGO), teachers can find many didactic materials: video tutorials, projects and lesson plans as well as worksheets. Comprehensive lesson plans for science, technology, engineering, math, maker, coding, and computer science come in a range of challenge levels and duration from 30 to 120 minutes. The content is available by free subscription. The second website is Microsoft MakeCode platform with multiple tools to learn programming with fun projects in different environments (LEGO Mindstorms, Minecraft, Micro:bit and others). It offers tutorials and project ideas.
Age range	7–14
Language	English, but there is also available information in Spanish, Danish, Swedish, German, French and many other languages
Principles	These LEGO and Microsoft websites are compliant with the five principles of the Learn STEM Pedagogical Model: 1. **Complex**: Leaners build problem-solving, critical thinking, math skills and self-improvement. 2. **Process-oriented**: Activities proposed are learner-driven, 3. **Holistic**: Its implementation conveys a learner-centred exploration, 4. **Practical**: There is a rich context beyond, allowing users to explore possibilities, optimise skills and be creative,

	5. Social: Encourages team work.
Lesson ideas	These tools can be used in programming and robotics lessons mainly in secondary school.
	Since education sets can be completed with specific measurement instruments, they can be integrated in other subjects like physics and mathematics.
	A standard robotics activity in secondary school may be planned as a two lessons project (total of 90 minutes) following these steps:
	Parking system project
	• Presentation of problem and examples from real life (cars parking monitoring systems).
	• Discussion of possible solutions, functionality and election of means (for instance to use an ultrasonic sensor to measure distances and to have a beep sound for signalisation, etc.).
	• Model design and construction (drawing a draft of the solution and building the model).
	• Connecting all the components.
	• Programming (in this case a simple program that will produce a beeping signal as the car approximates a wall).
	• Testing the model and the program. Evaluation of results, possible corrections or optimisation.
	• Presentation of the system and explanation of the selected solution to other learners.

	Example 9
Title	PHYSICS – The use of physics in engineering
Company or website	https://tryengineering.org/
Image	
Description	The platform provides an overview of a number of STEM projects. Classified according to difficulty level and user age. Physical concepts are being explored in a playful way, learner-driven, with open-ended challenges. There is support for the teachers with classroom activities, lesson plans and teacher resources. The lesson plans are clear and well documented: https://tryengineering.org/teachers/lesson-plans/ By selecting a lesson plans, you'll get an overview for every topic : 📄 Lesson Plans ⌨ Electricity and Magnetism ⌨ Engineering Design ⌨ Technology 👤 8-12, 12-14
Age range	4–18
Language	English
Principles	'Tryengineering' incorporates all five principles of the Learn STEM Pedagogical Model: 1. **Complex**: 'Tryengineering' allows teachers to select lesson plans of different levels of complexities, 2. **Process-oriented**: Most STEM project are learner-driven, 3. **Holistic**: 'Tryengineering' facilitates learner-centred exploration, 4. **Practical**: 'Tryengineering' projects will start from a rich context, 5. **Social**: 'Tryengineering' requires collaboration of learners and are linked to the environment.
Lesson ideas	Teachers can choose from a number of lessens. **Idea 1 : Internet of Things – Smart Buildings** https://tryengineering.org/teacher/smart-buildings-and-internet-things/

'Smart buildings' combines environmentally responsible design with cutting-edge computing technology. This lesson explores the practical, scientific, ethical and environmental issues that emerge in building 'smart buildings' that rely on 'internet of things'. Learners work in teams using resourced technology to design and perhaps later implement, smart building solutions to make their school a better place.

Age levels: 11–17

Objectives : Introducing learners to:
- The concepts 'smart building' and 'internet of things',
- Design principles and technologies that are used to create smart buildings,
- How computing can support solutions for the common good,
- How sensors, message passing and event handling implement 'smart building' technology.

Learners will be able to
- Explain what makes a building 'smart',
- Explain how sensors, event handling and message passing are used to support 'Internet of things',
- Design experiments to collect data on environmental and social needs of a physical environment,
- Develop a proposal for a solution to an identified need in a physical environment.

Idea 2 : Optics
https://tryengineering.org/teacher/an-eye-optics/

The goal of this lesson is to provide learners with an open-ended opportunity to explore and work with materials, make and share observations and build a fundamental understanding of the relationship between gelatin shapes and light. Open-ended exploration encourages creativity and problem solving useful to meet the final challenge of designing a lens system to improve vision.

Age levels: 10–14

Objectives: Introduce learners to:
- Light,
- Lenses,
- Assistive vision technologies.

Learners will be able to:
- Understand and apply knowledge about properties of light and lens shapes to solve a problem related to human vision,

	• Use lab equipment (lights, lenses, etc.) to design a solution to a problem, • Apply scientific methods and collect data to draw conclusions from evidence, • Develop and document a repeatable process.

	Example 10
Title	PHYSICS – STATICS: Building bridges
Company or website	https://www.cesdb.com/west-point-bridge-designer.html https://www.pbs.org/wgbh/buildingbig/lab/forces.html (Java needed!) http://pages.jh.edu/~virtlab/bridge/bridge.htm (Java needed!)
Image	
Description	The award-winning Bridge Designer software is now an open source. Download: https://www.cesdb.com/west-point-bridge-designer.html This software provides learners with a realistic introduction to statics and engineering through an engaging, hands-on design experience. This software provides you with the tools to model, test and optimise a steel highway bridge, based on realistic specifications, constraints and performance criteria. The objective is to create an optimal bridge design. An optimal design is one that satisfies all of the design specifications, passes a simulated load test and costs as little as possible. Features: • Design a virtual bridge, • Learn about statics, applied physics, engineering and design, • Have fun testing and improving your designs with your team. Creating the design is fast and easy, so you can experiment with many different alternative configurations as you work toward the best possible solution. The West Point Bridge Designer itself is quite similar to the computer-aided design (CAD) software used by practicing engineers and it will take care of the heavy-duty mathematical calculations, so that you can concentrate on the creative part of the design process.
Age range	12 and older
Language	English
Principles	Bride Designer follows and supports all five principles of the Learn STEM Pedagogical Model:

	1. **Complex:** The 'buildingbig' app gives an insight into the basics of force effects on constructions, while Bride Designer supports teachers and learners in the understanding of the complex system of the spread of forces in constructions, 2. **Process-oriented:** During the exploration and construction phase of building a bridge, learners can explore independently, 3. **Holistic:** The West Point Bridge Designer will introduce you to engineering through an authentic, hands-on design experience. Learners can investigate environmental effect of developments, look at the impact on urban planning, on the social network, etc., 4. **Practical:** The Bride Designer project will start from a rich context, 5. **Social:** Building bridges requires collaboration of learners.

Lesson ideas	**Idea 1:**
	
	 Build a scale model of a new bridge over a river that:
	 • Is strong enough, the strength will be tested,
	 • Contains five driving lanes,
	 • Is built to scale :
	     • Construction length scale 1:1500
	     • Construction weight scale 1:1.500.000
	 • Measurements:
	     • Span width = 1 km
	     • 5 traffic lanes
	     • the bridge is accessible for trucks up 50 tons
	 • Is beautiful, ecological and in harmony with the city.
	
	 The scale model must be cost effective:
	 • Example of cost calculation for the model materials:
	     • Paper : € 300 /sheet
	     • Rope : € 1500 /m
	     • 1 m tape : € 1000 /m
	     • Popsicle stick : € 500 /stick
	     • Glue : € 2000 /glue stick
	     • Wooden stick : € 600 /stick
	
	 The scale model and design will be presented at the end of the project.
	
	 Additional challenge on higher level: optimise traffic flow on the bridge, by installing direction changing traffic lights.
	
	 Project protocol:
	 1) Map your team progress on a white board
	 2) Record your work progress in a portfolio that contains
	     • At least 1 experiment (research question, hypothesis, analysis, validation, conclusion),

- The research (inspirational pictures, sketches, drawings, calculation, virtual material…),

3) Build a scale model,
4) Present your project

Idea 2: Building big

The effect of forces and materials on constructions :
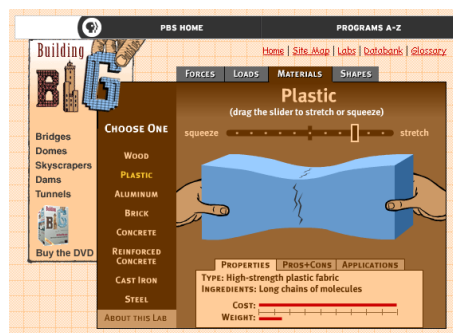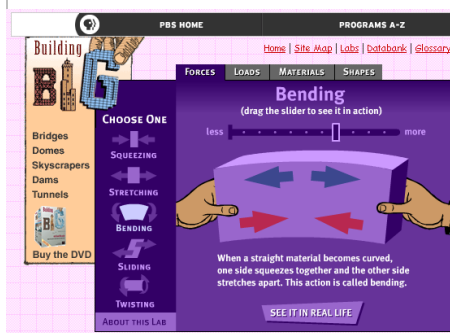
The effect of temperature and shape on constructions :
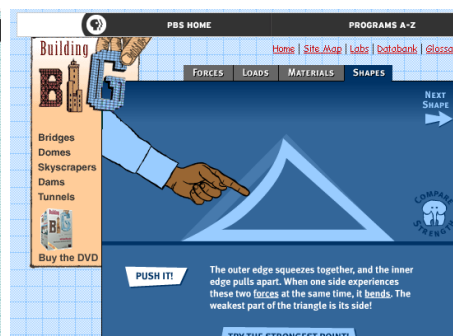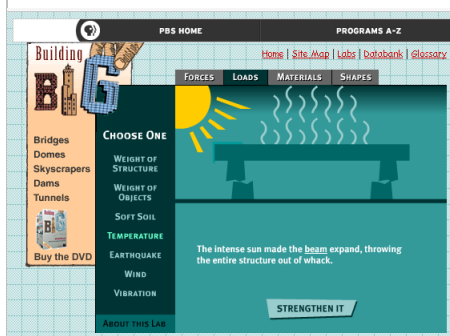
Idea 3: Virtlab Bridge

Learn about the effects of forces, materials, temperature and shape on constructions. This software allows you to design trusses. Trusses are composed of straight members connected at their ends by hinged connections to form a stable configuration. When loads are applied to the joints of steel trusses, forces are transmitted only in the

direction of each of its members. Thus, members experience tension or compression forces, but not bending forces. Trusses have a high strength to weight ratio and consequently are used in many structures, from bridges, to roof supports, to space stations.

In this simulation, trusses are created by attaching members to nodes (joints). First, nodal locations are specified; then the nodes are linked by members to create a structure. Once the structure is established, two of the nodes must be assigned as support nodes. One must be a "fixed" node, i.e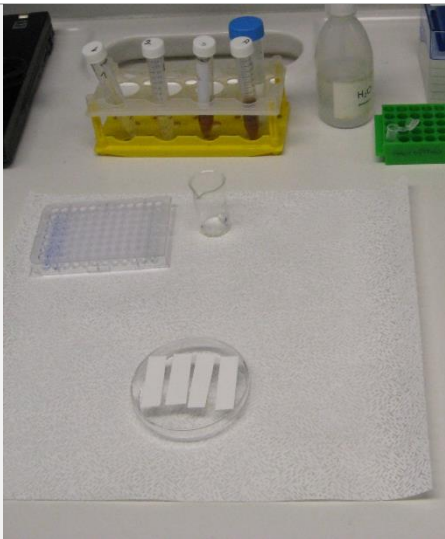., one that can provide support in both the x- and y-directions; the other must be a "rolling" node, one that can provide support in only the y-direction. Finally, one or more nodes can be assigned to bear loads.

Once these elements are specified, a click on "Calculate" will check your design. Another click will generate a complete force diagram showing compression/tension forces in each of the members and reactive forces at the support nodes.

Hands-on experiment:

Learners can do some simple experiments in solid constructions, using a piece of paper. By folding or rolling the paper and adding weight to certain positions, they learn about the basics of a statics.

	Example 11
Title	Biochemistry – glucose detection in solutions
Company or website	Laboratory suppliers can provide the necessary chemicals (examples are: https://www.sigmaaldrich.com or https://www.carlroth.com or https://de.vwr.com), but no information concerning the proposed experiments. For this see below.
Image	
Description	Sugars play an essential role for our metabolism. Disruption of our sugar metabolism can cause dramatic health issues like diabetes. Patients who suffer from this disease have to monitor their blood sugar concentrations on a regular basis. Commercially available measuring devices comprise test strips or biosensors. In both cases, biochemical reactions are used to detect a molecule and connected to a transduction process allowing the generation of a signal. In case of test strips, the signal is a colour change; in case of a biosensor, it is an electrical signal which can be displayed.
	Parts of this detection scheme can be imitated in a lab or classroom. Here, learners can experiment themselves in order to better grasp how bioanalytical systems are constructed and operate. Learners will, however, need an introduction to the characteristics of enzyme functioning and redox reactions. Furthermore, teachers will be able to initiate a conversation about healthy diets and the consequences of eating too much sugar.
	All that is needed is a combination of enzymes, a colour changing redox indicator, paper and glucose solutions. Materials and solutions for detection of glucose can be easily purchased from lab supply websites and used repeatedly.
Age range	12–18
Language	Any
Principles	This experiment incorporates all five principles of the Learn STEM Pedagogical Model: 1. **Complex:** Teachers are free to introduce information about enzymes and biochemical reactions in any complexity,

2. **Process-oriented:** Learners will have their own set of materials and can work in their own pace,
3. **Holistic:** Learners can self-test hypothesis using various solutions and actively debate health benefits of a diet. They learn how biochemical reactions can be coupled to transduction which allows a visualisation of the information required. Since this can be done in different ways, they learn to combine several classical disciplines,
4. **Practical:** Learners will learn to handle lab equipment,
5. **Social:** The experiment is best done in groups.

Lesson ideas	**Glucose detection by colour change:**

Background:

As enzymes are substrate specific, glucose oxidase (GOD) can be used to react with glucose in solutions. GOD oxidises the reducing sugar D-glucose to D-glucono-1,5-lactone. During this reaction, oxygen is converted to hydrogen peroxide. For each molecule of oxidised glucose, one molecule of hydrogen peroxide is created:

$$\text{D-glucose} + O_2 \xrightarrow{\text{GO}} \text{D-glucono-1,5-lactone} + H_2O_2$$

In a second reaction, hydrogen peroxide is used by the enzyme peroxidase (POD) to oxidise the redox indicator 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS). Reduced ABTS is colourless to light green, oxidation will make this reagent turn dark green. Thus, when combining both enzymes and ABTS and adding glucose solution, the reaction can be detected due to a colour change:

$$H_2O_2 + \text{ABTS} \xrightarrow{\text{POD}} \text{ABTS}^{\bullet+} + 2H_2O$$

Protocol:

Per workstation you will need:

- 4 filter paper strips 1 cm x 4 cm (cut from i.e. Whatman filter papers, grade 1)
- petri dish
- plastic pasteur pipettes 3 ml
- glucose oxidase solution (1 mg/ml, app. 220 units/mg)
- peroxidase (1 mg/ml, app. 1000 units/mg)
- ABTS 10 mg/ml

Per class you will also need:

- 4 centrifuge tubes 15 ml (or any container with lid) filled with
  a) Coke
  b) Coke Zero
  c) glucose solution (5%)
  d) water

Each group will place the four paper strips into the petri dish and mark one end with a pencil. On this mark, all three reagents (GOD, POD, ABTS) will be combined:
- add one drop of GOD with the Pasteur pipette on top of the mark, wait 1 min to dry,
- repeat with POD (new pipette),
- repeat with ABTS (new pipette).

After drying the test strips are ready to be used for the detection of glucose in solutions. Use a new pipette adding one drop of solution a) to the first test strip, one drop of solution b) to the second test strip etc. As coke and glucose solution contain glucose, test strip a) and c) are expected to show a green colour change since glucose oxidase will convert the substrate.

As an extension one may prepare more test strips and test solutions of different glucose concentration. By this the students can see in which concentration range the prepared strips can indicate the presence of glucose.

	Example 12
Title	Water – the basis of life Aspects of wastewater purification
Company or website	Laboratory suppliers can provide the necessary chemicals (e.g. https://www.sigmaaldrich.com or https://www.carlroth.com or https://de.vwr.com), but no information concerning the proposed experiments. For this see below.
Image	
Description	All living organisms require water for their cells and metabolism. Many plants and animals even use rivers, creeks, oceans etc. as habitat. Humans use water in numerous situations in everyday life – to stay hydrated, to cook, brush their teeth or clean their clothes. To guarantee a sufficient supply of this resource, water bodies have to be protected and managed sustainably. Most of our drinking water is gathered from springs, rivers or ground water. After usage, wastewater must be treated in a plant before it can be reintroduced into the water cycle. This process is subjected to great regulations in order to fulfil microbiological, chemical and physical standards. The following lab exercise recreates some of the steps occurring in a wastewater treatment facility. Learners can actively experience what components are being removed with each additional step and what pharmaceuticals will be directed back into the environment. This lab exercise can be used in combination with courses on water cycles and environmental conservation.
Age range	16–18
Language	Any
Principles	This experiment incorporates all five principles of the Learn STEM Pedagogical Model: 1. **Complex**: Teachers are free to introduce information about water cycles, chemical reactions and environmental protection in any complexity, 2. **Process-oriented**: Learners will have their own set of materials and can work in their own pace,

	3. **Holistic**: Learners will combine practical lab exercises and chemical analysis and learn about aspects of detection methods, health and environmental benefits, 4. **Practical**: Learners will learn to handle lab equipment, 5. **Social**: The experiment is best done in groups.
Lesson ideas	Recreate the numerous mechanical and chemical cleaning steps in a wastewater treatment facility and analyse water quality after each phase. Scenario: Water quality of a lake which supplies water to a small town requires evaluation. Thus, an analytic lab was contracted to take samples and analyse water quality. Learners are asked to form groups and evaluate water quality and test again after different cleaning methods involved in wastewater treatment. **Protocol:** Per workstation you will need: - 1.5 ml reaction tubes - 15 ml reaction tubes - 50 ml reaction tubes - 100 ml beaker - 4x 25 ml beakers - 2x funnels - 6x filter paper - activated carbon Optional: - laboratory stand - oxygen and conductivity sensor - squeeze water bottle to clean the sensor - tissues to clean the sensor - laptop Per class you will need: - magnetic stirrer with integrated hot plate - 4x magnetic stirring bars - 1.2% iron(III) chloride solution - concentrated sodium hydroxide solution - test strips (pH, nitrate/nitrite, carbonate, chloride, phosphate, ammonium) Teachers will prepare water samples with a total volume of 200 ml mixing the following ingredients: - 125 µl aspirin solution (grind one tablet and add 10 ml water) - 125 µl paracetamol solution (grind one tablet and add 10 ml water) - pieces of paper - 360 mg sodium chloride - 200 mg sodium phosphate - 250 mg ammonium nitrate - 3 table spoons of soil add water to a total volume of 200 ml

Teachers will further prepare positive and negative controls for detection of aspirin and paracetamol in water samples:
- positive testing aspirin solution: transfer 1 ml of the 10 ml aspirin solution into a 1.5 ml reaction tube, repeat for paracetamol
- negative testing aspirin solution: add 1 ml of water to a 1.5 ml reaction tube, repeat for paracetamol

Water samples can be analysed as follows:

Water analysis:
Fill a 15 ml reaction tube with the sample and use test strips for classification of:
- nitrate
- nitrite
- chloride
- phosphate
- ammonium
- carbonate (i.e. hardness of water)
- pH

Optional: Fill 40 ml of the original sample into a beaker and use sensors to measure:
- oxygen concentration
- conductivity

Mechanical cleaning:
Mechanical cleaning removes sand and paper.
Place a funnel and filter paper onto a new 15 ml reaction tube. Pour the sample from the used 15 ml tube into the funnel. Transfer two times 1 ml of the filtrate into 1.5 ml tubes.

Chemical cleaning:
Chemical cleaning removes phosphate, phenols and amino acids.
Add 2.5 ml of iron(III) chloride to your filtrate in the 15 ml tube, shake to mix. Transfer to a new beaker and add a magnetic stirrer bar. Heat and mix solution at 80°C for 5 min on the magnetic stirrer. Cool down solution and then filter through paper again into a new 15 ml tube. Transfer two times 1 ml of the filtrate into 1.5 ml tubes.

Physical cleaning:
Physical cleaning removes toxins and hydrocarbons.
Add a tea spoon of active carbon to a 50 ml tube and transfer the filtrate in the 15 ml tube, shake to mix. Filter through paper again into a new 15 ml tube. Transfer two times 1 ml of the filtrate into 1.5 ml tubes.

Repeat water analysis with the filtrate in the 15 ml tube.

Testing for pharmaceuticals:

Aspirin:

Add 250 µl of iron(III) chloride solution to each 1.5 ml tube (including positive and negative testing controls), shake to mix. Then, add 100 µl of sodium hydroxide solution to each tube, shake to mix. Record colour of each solution and note whether aspirin is present.

Paracetamol:

Add 250 µl of iron(III) chloride solution to each 1.5 ml tube (including positive and negative testing controls), shake to mix. Record colour of each solution and note whether paracetamol is present.

Conclusions:

All results should be recorded, compared and discussed before, during and after the cleaning process as well as evaluated if they meet the national standard for portable water quality.

Alternatively, teachers can create a scenario where samples were taken from various locations along the water way including or excluding certain components and before and after wastewater treatment. For instance, phosphate and nitrate may be added to one sample as indicator for fertiliser residue from agricultural land. Each group would be given one sample to analyse and guess where it originated from. Additionally, the original sample can be filled into separate 15 ml reaction tubes and water quality analysed separately after each cleaning step.

About Learn STEM, the European Alliance for Innovative STEM learning in schools:

We need innovative and better school education in Science, Technology, Engineering and Mathematics (STEM) as key sectors for our future life, work and society. The European Alliance **Learn STEM** focuses their interrelation and integration in cross-disciplinary and reflective STEM education and pedagogical methodologies. Main goal of **Learn STEM** is to improve the quality and efficiency of STEM learning in secondary schools. Consequently **Learn STEM** aims at increasing the pupils' interest in STEM and building STEM competences. Therefore **Learn STEM** designs and provides pedagogical methods and tools for secondary schools to explore and solve real life questions. Thus, **Learn STEM** supports and contributes to the key objective of the European Education and Training 2020 Strategy (ET 2020) that fewer than 15% of 15-year-olds should be under-skilled in reading, mathematics and science.

Moreover, the **Learn STEM** project will also address the need to enhance knowledge of and about science as a precondition to prepare Europe's population to be actively engaged, responsible citizens as well as conversant with the complex challenges facing society. In the PISA study 2015 most students of expressed a broad interest in science topics and recognised the important role that science plays in their world; but only a minority reported their participation in science activities. In addition, teachers still declare they need more professional development linked to tailoring, diversifying, and innovating teaching practices. Thus, **Learn STEM** aims at strengthening secondary schools capacity to develop skills in subjects such as science, technology, engineering and mathematics through innovative and interactive pedagogical methods and approaches. The project will provide teachers and schools with a pedagogical model and educational tools to support pupils to connect with the 'real-life' applications of STEM, in particular related to Internet of Things (IoT) and robotics, which represent two very popular sectors in the technological field.

Under the leadership of Dr. Christian M. Stracke from the Open University of the Netherlands, **Learn STEM** brings together nine Partners from six European countries (The Netherlands, Belgium, Germany, Italy, Lithuania and Portugal) developing the **Learn STEM** Pedagogical Model and the Inquiry learning package. All these contents will be integrated in the open online learning environment and offered as a free course for teacher training.

More information about **Learn STEM** online:
http://www.Learn-STEM.org

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