Learn STEM

Innovative STEM learning in schools

Pedagogical Model

for Innovative STEM Learning and Teaching

http://www.learn-STEM.org

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The Pedagogical Model for Innovative STEM Learning and Teaching

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The Pedagogical Model for Innovative STEM Learning and Teaching

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Executive Summary

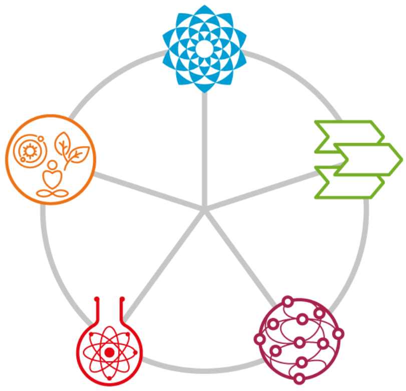
Learn STEM is the **Pedagogical Model for Innovative STEM Learning and Teaching**. It comprises a general framework for improving learning and teaching of Science, Technology, Engineering and Mathematics (STEM) in secondary schools. It has been developed by nine partners from six European countries (The 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.

Learners need to acquire strong mathematical and scientific abilities in order to be competitive in the 21st century work environment. Thus, development of profound knowledge and skill sets in team work, rational thinking and investigative and creative work which learners can use in all areas of life, is essential. **Learn STEM** addresses this need to improve the quality and efficiency of education and training as well as the need to enhance knowledge in STEM topics. It will prepare Europe's residents to be actively engaged, responsible citizens as well as conversant with the complex challenges facing society in the future.

The pedagogical model **Learn STEM focuses on the learner** who shall become the owner of their own learning processes. Thus, the role of teachers needs to change: teachers should facilitate such learning processes and act as coaches. However, teachers may also guide and supervise the learning process. **Learn STEM** can be combined with other approaches and methodologies to learn and teach STEM.

Learn STEM is based on educational theories and positions and focuses mainly on the following five characteristics of the learning process:

- Complex
- Process-oriented
- Holistic
- Practical
- Social



Learn STEM objectives comprise three elements: knowledge, skills and competences. Learners gain STEM knowledge and build STEM skills. Through reflection and **repeated training**, they build STEM competences based on assimilation and accommodation. The learning process should be interdisciplinary and holistic. Learning is considered a process going through **iterative improvement cycles**. Here, the model allows flexibility since the teacher can act more as a coach or as a tutor depending on the situation in the respective educational system. **Practical courses** are valuable tools during the learning process as they allow to expand knowledge, but also to develop practical skills. Learners will use and demonstrate their obtained knowledge and skills in everyday life problems and successfully **apply their developed competences** in new situations. **Learn STEM** incorporates the complexity of STEM learning activities related to the various STEM disciplines as well as to the interrelation with other areas: **Learn STEM** connects the world of learners with our society and provides insigths into the complex relations between **STEM and society**.

1. Vision and Objectives for Learn STEM

Learn STEM, the **Pedagogical Model for Innovative STEM Learning and Teaching**, addresses the current demand for new models due to global changes. This Pedagogical Model provides a didactical framework which can and needs to be adjusted to the specific situation and context regarding the different schools, regions, educational systems and cultures in Europe and worldwide. STEM focuses on the interrelation and integration between these four topics: Science, Technology, Engineering and Mathematics (STEM).

Learn STEM provides pedagogical methods and learning tools for secondary schools to improve STEM education. This is based on real-world problems and shall stimulate professional carriers in this direction which can eventually assist in solving real-world challenges of society.

1.1 Vision, Mission and Main Goal of Learn STEM

The **Vision** of **Learn STEM** is to innovate and improve school education in STEM as key subjects for our future life, work and society. This will be achieved by focussing on the interrelation of STEM topics, reflective STEM education and pedagogical methodologies.

The **Mission** of **Learn STEM** is to increase the learners' interest in STEM and their STEM competences (in order to promote a professional career in STEM).

The main goal of **Learn STEM** is to improve learning and teaching STEM and in particular the quality and efficiency of STEM education in secondary schools.

1.2 Target Groups of Learn STEM

Direct target groups of **Learn STEM** are:

1. pupils in secondary schools studying STEM,
2. STEM teachers in secondary schools being responsible for STEM education,
3. science museums, technology demonstration centres, pupils' and field labs (acting as part of a complex education, designed to promote science education and helping to generate future scientists and engineers),
4. educational and training providers for teachers' continuous professional development,
5. public authorities responsible for STEM curricula.

Indirect target groups of **Learn STEM** are:

- societies which the learners are growing up in,
- pupils’ parents,
- private and public initiatives supporting STEM (such as makerspaces),
- policy makers,
- other stakeholders (e.g., public and private organisations, research centres, universities, trade unions, etc.).

2. The Basis for Learn STEM

Learn STEM is based on general theories, models and principles about learning. They have been combined and integrated for an innovative pedagogical model. The **Pedagogical Model** is based on a general teaching methodology and didactical aspects and supports the guiding principles of STEM, namely the understanding of phenomena as well as exploring possible solutions for a given problem.

Learn STEM is also built on practical experiences for different types of school education systems which have been reviewed and analysed. Furthermore, it benefits from experiences of learners, who are interested in STEM and of university students starting study courses in STEM.

Learn STEM shall not replace valuable and successful educational traditions and methods, but enhance them by adding an innovative methodology which can be used and applied in STEM. As a theoretical concept, it can also be transferred and adjusted to other fields and contexts, such as social sciences etc.

The following aspects are of particular importance:

2.1. Outcome-orientation instead of input-orientation

Traditionally, educational systems were defined by input-based learning. Hence, as their main function, teachers had to 'convey' knowledge to their learners. Nowadays, the focus needs to shift towards outcome-orientation as knowledge expands on one hand or can be outdated quickly due to rapid technological progress on the other hand. The entire learning process has got the competences as key long-term outcome (Stracke 2015).

2.2. Continuous improvement cycle

The continuous improvement cycle was developed and introduced by the philosophies of total quality management after the Second World War. At the beginning of the 21st century, it had been adapted for learning processes and education by the IDEAL framework: IDEAL stands for the four phases Initiate, Do, Evaluate and Act and the learner-orientation as the general focus of all learning processes (Piaget 1953; Dewey 1966; Rousseau 1968; Vygotsky 1988; Stracke 2006, 2014).

The 'Agile in Education Compass' (see Van Dijk et al. 2016) provides a guideline for the pedagogical design of **Learn STEM**. The centre of the compass is the iterative focus supported by the elements of Trust, Visible Feedback and Reflection, Culture and Collaboration. The goal of this compass is to create a congenial situation for learners in a social constructive learning environment. Here, the learner follows iterative sprints based on complex meaningful learning tasks which are related to the learner's emotional and cognitive level.

2.3. Knowledge, skills and competences for learning STEM

Learn STEM is related and connected to the concept of knowledge, skills and competences (KSC) and the abilities of learners to build them. **Learn STEM** is based on the learner-centered principles where learning is influenced by various factors, such as cognitive, metacognitive, motivational, affective, developmental and social factors as well as diversity among individuals. In addition, **Learn STEM** is following the learner-centered philosophy which Dewey and many others have recommended (Dewey 1966; Stracke 2015). The learner-centered education is placing learners into the core focus of the learning process through the design of appropriate learning objectives, environments and tasks for self-directed or teamwork learning.

2.4. Roles of teachers and learners

Learn STEM is based on a strong relationship between teachers and learners. Depending on the learner’s level of knowledge, skills and competences in STEM, teachers select the appropriate approach and scenario. The teacher may:

1. prepare the learning environment and set the broad parameters of the learning opportunities and their design and content, or
2. discuss and negotiate the planned activities developed and proposed by the learner.

In the first scenario, the teacher ensures that designed lessons cover all the defined learning objectives and all the knowledge, skills and competences to be addressed. The teacher plans assessments for monitoring and measuring the effectiveness of learning objectives. Finally, the teacher guarantees that the learners' grades are consistent with the assessment data and the observed developments of the learner's knowledge, skills and competences.

In the second scenario, the learner realises and analyses the planned activities and discusses conclusions and achievements with their teacher afterwards. Here, the teacher is taking on the role of a mentor and coach for the learner.

In both cases, teachers have to supervise the learning process in order to implement the repeated engagement with basic questions and development of practical skills.

For STEM teachers, the **Learn STEM** approach also means that they have to uphold a life-long-learning attitude. This relates to the supervision of the learners improvement cycles, but also to innovative developments in STEM.

3. The Pedagogical Model Learn STEM

Learn STEM is the **Pedagogical Model for Innovative STEM Learning and Teaching.** It comprises a general and holistic framework for improving learning and teaching of Science, Technology, Engineering and Mathematics (STEM) in secondary schools. **Learn STEM** can and needs to be adjusted to the specific educational situation and context.

Learn STEM can be considered a combination and adaptation of the educational theories and positions based on social constructivism focusing on the following five characteristics:

- Complex
- Process-oriented
- Holistic
- Practical
- Social

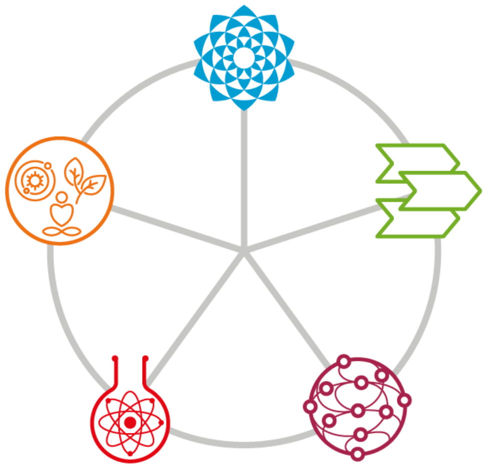


Figure 1: Five characteristics of the **Learn STEM** model

We believe that learners should become the owners of their own learning processes and that the role of teachers needs to change: teachers should facilitate such learning processes and act as coaches. In addition, they also should guide and supervise the learning process. Furthermore, **Learn STEM** can be combined with other approaches and methodologies to learn and teach STEM and is not the only suitable approach to be followed.

Learn STEM provides teachers with not only general guidelines but rather tools for their practical school education in STEM. We refer here in particular to the **Inquiry Learning Packages** and training modules which can serve as examples to be followed.

Learn STEM objectives consist of three elements: knowledge, skills and competences. Learners gain STEM knowledge and build STEM skills. Through reflection and repeated training, they build STEM competences based on assimilation and accomodation. Learners can use and demonstrate their knowledge and skills in daily life and successfully apply their assimilated competences in new situations. **Learn STEM** incorporates the complexity of STEM learning activities. Besides a variety of competences learners develop a growing mindset. **Learn STEM** connects the world of learners with our society and provides insigths into the complex relations between science, technology and society. This includes professional perspectives for scientists and engineers.

Thus, **Learn STEM** meets the demands of the society for independent and well-educated citizens as well as for future innovative professionals working in STEM.

3.1. Learn STEM is Complex

Learn STEM is **complex** in regards to the specificity of the covered disciplines. It is **interdisciplinary** as it connects the numerous subjects and underlines common principles and approaches.

STEM is a complex system incorporating specific characteristics of the different fields. Thus, **Learn STEM** covers a variety of subjects, terminologies and scientific laws. **Learn STEM** aims to create profound knowledge, skills and competences based on a continuously increasing level of complexity related to the learners' development.

Learn STEM is **interdisciplinary** since it aims to recognise that the different fields and subjects are not separated and that they can be analysed from different points of view. Thus, **Learn STEM** is not partitioning, but seamlessly integrating STEM subjects into learning processes and activities of learners. Real-world problems can demonstrate the demand for a complex approach and thinking. In iterative cycles learners will recognise similarities and common laws in STEM.

Therefore, a **multidisciplinary approach** should be followed and is realised via different approaches: teaching and learning STEM can address cross-disciplinary topics for gaining knowledge, acquiring skills and building competences, coherent with gathering and using of evidence, e.g., through the understanding of a set of BIG IDEAS in STEM (Harlen 2010; Harlen 2015). Some examples may illustrate this:

1. All material in the universe is made of very small particles. The appearance of these materials is dependend on the interaction of these small particles (protons, electrons, atoms, molecules, agglomerates, crystals etc.)
2. The total amount of energy in the universe is always the same, but energy can be transferred from one form into another. It can also be stored in chemical compounds and thus, transformed during chemical and biochemical reactions.
3. Complex biological organisms are organised on the basis of cells as functional units constituting of an arrangement of chemical compounds.

In addition, **Learn STEM** has to represent the complex relations between science, technology, engineering and maths: for example, technology can grow on the basis of applied sciences, but can also develop independently from sciences. Vice versa, science can develop independently from technology or may be stimulated or initiated by technologies - as new disciplines are evolving often based on latest technologies.

Learn STEM is complex from the perspective of the learners’ development since it seeks to empower learners to use their abilities, competences and (self-) reflective learning as a support for their emotional and social development.

3.2. Learn STEM is Process-oriented

Learn STEM is **process-oriented** in regards to the learning activities. Learners can explore STEM in a self-regulated and creative way through exploration and creation. In **Learn STEM**, processes are **iterative**, focusing on the learners' development but also train basic skills and build profound knowledge.

Learn STEM is an iterative learning process with continuous improvement of the learner's competences, skills and mental strategies. **Learn STEM** focusses on the following processes:

- Explore
- Build
- Reflect and
- Improve.

Figure 2: **Learn STEM**'s continuous improvement cycle

These **Learn STEM** processes can be applied in many different ways. Table 1 gives an overview of different concepts and usage of the four steps involved in the continuous improvement cycle:

Table 1: Examples for iterative learning processes according to the Learn STEM model

Explore	Build	Reflect	Improve
group formation and problem analysis	solution design and development, skill practise	result evaluation	result discussion and solution adjustment
initiation and hypothesis generation	investigating and practising skills	result analysis	conclusions
discovery	idea creation solution design	idea development	dissemination and impact evaluation
problem finding, information	design of solution pathways	communicate, discuss, analyse	new ideas

This focus is process-oriented as the learner has to develop applicable skills and competences. Learning will be supported by visible feedback and reflection. Practising, repeated training and applying existing knowledge reinforce abilities, skills and competences. The learning process encourages ownership and will show continuous growth.

Learn STEM processes are following the principle of a continuous improvement cycle: **Learn STEM** processes are usually repeated several times following the principle of iterative progress with sprint cycles, hence ideally leading to improved results and STEM competences after each cycle. The reoccuring contact with general STEM questions in a designed learning environment and solving everyday life tasks shall stimulate skill development and build general knowledge.

Learners, who build STEM competences in one or more fields, will be given the opportunity to use these competences in the following cycle for a new task. Such iterations will ensure the continuous improvement and build up of STEM competences. Here, it is the teachers' responsibility to create a learning environment where profound knowledge, skills and competences will be built through encouraging new tasks solving or raising problems and questions. Furthermore training modules can help to solidify acquired algorithyms and knowledge and help the learners to gain confidence in using them. Thus, the improvement cycle illustrated in Fig. 2 will be repeated several times and can be realised via repeated training and self-regulated learning. This will not simply result in a linear improvement, but will comprise numerous interrelations between the various tasks and learning cycles related to different STEM fields.

Most importantly, the iterative progress of the **Learn STEM** processes is flexible and allows for different pathways and options. This can be achieved by adjusting the curriculum applying defined and interconnected topics or following the principle of self-regulation by learners' themselves or in small working groups: learners can choose from different options either directly prepared and provided by the teacher or discussed during continous reflection.

3.3. Learn STEM is Holistic

Learn STEM is **holistic** in regards to the subjects, their connections and the methods to teach. **Learn STEM** focuses on understanding general ideas in STEM rather than accumulating specialised knowledge. **Learn STEM** emphasises the ethical component of STEM and contributes to the learners' personal development.

STEM explains and explores our environment on different levels using different models and even ‘languages’. However, there is no boundary between the different areas and hence interdisciplinarity is an essential criterium for present and future developments. Complex systems are not simply the sum of many components, but rather holistic due to their various interrelations. This has led to the development of different view points in STEM. The holistic view becomes continously important in order to understand sophisticated systems such as living organisms. This also requires new tools and algorithms for analysis. **Learn STEM** focuses on the system view point and stimulates learners’ attention on careful observations and conclusions. An integrated, holistic approach is consequently a solid feature of **Learn STEM**. It further facilitates the link to social sciences where this kind of approach has a long tradition.

STEM influences the society in various ways and on different levels. Through **Learn STEM**, learners get introduced to these interactions and consequently the responsibility of scientists and engineers. STEM skills and competences built by the learner will in turn affect and serve the society. STEM learners, who choose to become scientists, engineers or entrepreneurs, may develop new technologies or discover new scientific phenomena which can change peoples’ life.

Debates on ethical aspects of STEM developments may help to understand the rather complex mechanisms in the development of societies. **Learn STEM** connects STEM with social aspects as well as other areas of the humanities such as art.

3.4. Learn STEM is Practical

Learn STEM is **practical** in regards to the learning experiences and their applications. **Learn STEM** supports learners in gaining knowledge, acquiring skills and building competences through **real-world experiences and observations. Learn STEM** leads to action and (co-) creation with **enthusiasm** by creating and utilising **motivation.**

Learn STEM practice is embedded into an approach where learning arises from getting real-world lessons and learning by experiencing. Learners will be actively engaged and learn through co-creation with others.
Practical experiments are not only essential for the learning process, but also for the development of practical skills. Reoccuring exercices will further help to consolidate self-confidence of the learner. Practical lab work can be used to **apply knowledge** and **practise skills**, but also to **develop creativity** and thus, follow the iterative learning cycle. Practical exercises in a proper environment (such as an explorative environment, chemical laboratory or manufacturing industry) may additionally stimulate learners' interest and engagement.

An important aspect of practice is **real-world contact**, e.g., with business, research and industry. Impressions from the real-world can stimulate creativity and motivation. In addition, it offers the possibility to gain insights into potential professional careers and may encourage learners to start a vocational development in STEM topics including a university study. Besides companies, interactions with **research institutions** can provide a unique experience. Through interactions with students, an exclusive situation can be exploited since communication occurs featuring a rather small age difference.

3.5. Learn STEM is Social

Learn STEM is a **social activity with human interaction and emotional involvement.** The learning process is **learner-centered** aiming to impact individuals and the society by association. **Learn STEM** is inclusive, gender balanced and values diversity.

Learn STEM is social in relation to the learning environment and the learning impact. It happens constantly; it is a social activity and facilitates relationships between the learner and other learners or stakeholders (such as teachers, coaches, parents, experts). It also involves team work for problem solving. Thus, learning happens via social interactions within and outside of school. The intersubjectivity by discussing views among the different stakeholders helps learners to create new insights and meanings, increase motivation and enforces new knowledge exchange or even collaboration.

The learning environment should be safe for the learner. This means that learning takes place in a trusted environment. Human diversity and self-directed learning are core elements to become involved actively and emotionally and generate commitment.

There is close interaction of the society with the STEM area. Social developments can stimulate science and technology to find proper solutions. But STEM also strongly influences the society by providing new technical or technological achievements which impact everyday life. An effective interaction between both - under consideration of environmental and global aspects - is essential and will impact the prosperity in the development.

4. Implementation and Usage of Learn STEM

Learn STEM is the **Pedagogical Model for Innovative STEM Learning and Teaching.** It is a general and holistic framework for improving learning and teaching of Science, Technology, Engineering and Mathematics (STEM) in secondary schools. **Learn STEM** combines innovative key learning skills and competences:

1. Empathy and motivation
2. Self-regulated learning and learning how to learn
3. Critical thinking and media literacy
4. System thinking and problem solving
5. Exploration and experiments
6. Learning cycles and repeated training of basic knowledge and skills
7. Creativity

These principles will be applied and implemented for all **Learn STEM** activities, however with different relative contributions. They can be realised via various methodologies and formats.

Learn STEM is intended to stimulate interest, ability and motivation in dealing with different aspects of STEM and thus, encourage more young people to seek a professional STEM career.

A variety of strategies can be followed to develop and strengthen the learners' interest towards STEM and to involve the different stakeholder groups. During the **Learn STEM** programme, STEM teachers will provide information and organise practical components or supervise the self-regulated learning process of learners. Contact with everyday life problems to be solved and the development of projects will be repeatedly organised by STEM teachers. This process is supported by contact with university students, researchers and industry partners and their employees. Ideally, this will increase competences and motivation and thus, may endorse learners to choose STEM careers. Figure 3 illustrates these aspects schematically.

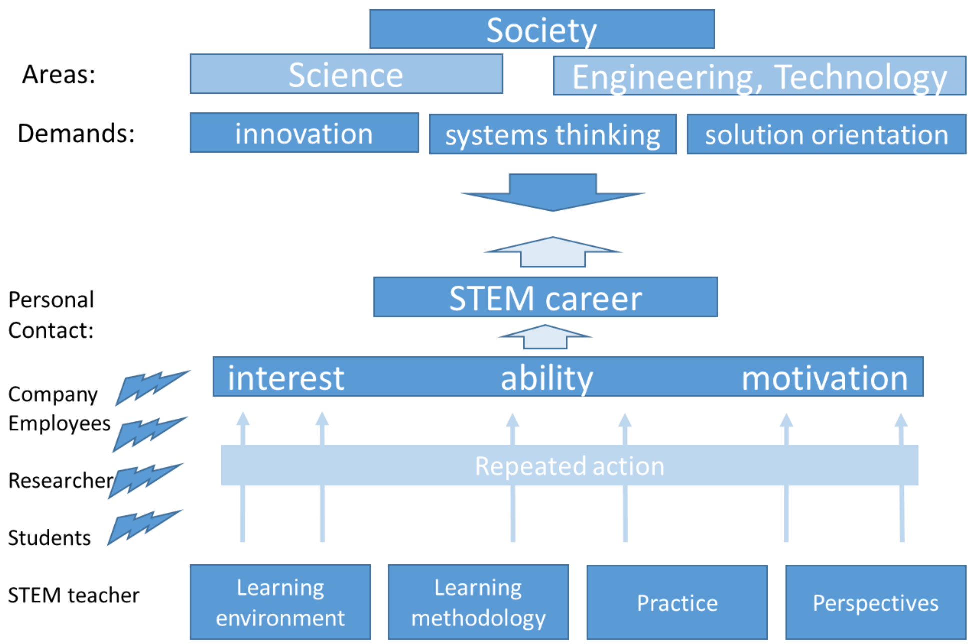


Figure 3: Various factors contributing to the development of stronger STEM interests

Learn STEM is designed to help learners to better understand the impact of the rather 'abstract' STEM subjects on the real life of individuals and communities, stimulating their sense of creativity.

Learn STEM is exemplified in the following two profiles for different objectives, situations and contexts: Internet of Things (IoT) and Robotics.

4.1. Learn STEM Profile: Internet of Things

Internet of Things (IoT) engages teachers and learners of secondary schools in learning activities by exploring and giving possible solutions to real-world problems. Moreover, integrating IoT devices into the classrooms can help to create interrelations between Science, Technology, Engineering and Mathematics (STEM).

<u>How does the Internet of Things (IoT) link to STEM teaching and learning?</u>

The Internet of Things is basically a network of several devices which are attached to a computational network allowing the interaction between the components and the exchange, analysis and storage of any kind of information.

The main reason to implement IoT in the education sector stems from the fact that IoT enhances education itself and provides advanced value to its structure and environment. As schools incorporate IoT for learning, this will promote a higher level of personalised learning, leading to a learner-centered approach.

IoT can be integrated into the five characteristics of **Learn STEM** (i.e., complex, process-oriented, holistic, practical and social):

Learn STEM is Complex. In a world where (almost) everything is connected, the **Learn STEM** approach can be valuable to analyse and recognise different fields of STEM which are also interconnected. The use of digital technologies facilitates this process supporting learners to separate and more clearly investigate the complex relations among STEM.

Nowadays, it is very common to see a child already playing with smart devices. Technology is becoming more and more part of various areas of everyday life.

For example, by combining different STEM subjects, learners can study microcontrollers and microprocessors, sensors, actuators, communication technologies and platforms while analysing and/or building their own IoT experience. For facilitating this process, teachers can use basic equipment and platforms to demonstrate everyday life applications of IoT, such as: smart homes, smart farming, tracking deliveries, etc. This approach will enable the learning process and motivate learners, both boys and girls, to continue their learning adventure in STEM subjects.

The use of IoT in the classroom has the potential to solve many problems and remove the barriers that often hinder education such as physical barriers, time, location and language. Implementing IoT as part of an education strategy may assist faster learning and greater interest of learners with diverse backgrounds and skills.

For this purpose, educators must develop a strong knowledge base about how to leverage the IoT to enhance quality of education and prepare learners to be active contributors to, and beneficiaries of, this educational integration.

IoT brings together a complex mixture of STEM subjects: Computing involves studying how internet works including the protocols that help to transmit data accurately and securely. In design and technology, products are designed and tested and have embedded programmable devices at their core, with inputs and outputs that serve a purpose and solve problems.

Without the statistical skills taught in mathematics, such as sampling, calculating the mean and employing mathematical relationships, the IoT is simply a mass of data that tells us little. Moreover, in science, sensors are used to collect and log data. Therefore, by using IoT, learners can draw conclusions and link data sets on plants, animals or other systems.

Learn STEM is process-oriented. Self-regulated learning aims to create motivation and learning strategies that learners utilise to achieve their learning goals. Self-regulated learning is defined as the degree to which learners are metacognitively, motivationally, and behaviorally active participants. A combination of cognitive, metacognitive, motivational and behavioral processes is needed for the pursuit of learning goals.

Within these processes, IoT provides a broader perspective to learners by gaining knowledge with a better understanding and interaction. This will encourage and enhance their inquiring minds and their creativity to stimulate their sense of initiative. Learners can even decide to improve their learning process by forming small teams with friends or teachers. In the latter case, real-world problems are discussed in classrooms by the educational professionals and learners are encouraged to find answers to these problems. Moreover, learners can increase their knowledge exploring the method of repeated actions that encourage them to find answers independently.

IoT technologies – such as digital tools which support operations, communication, analysis and decision making in every part of the modern organisation - follow the processes behind the production systems. In particular, a real-world problem has to be firstly explored in order to collect information before results can be interpreted. This can be accomplished by individual learners or small working groups. Afterwards, learners can choose from different options to design possible solutions which need to be evaluated and further discussed. Finally, they gather suggestions for a possible future improvement. Thus, IoT complies with the four steps of the continuous improvement cycle (explore, build, reflect and improve).

Learn STEM is holistic. Using IoT in the classroom has the potential to remove barriers that often hinder education such as location, language and economic standing. IoT will not only help to gain a better understanding in informatics and mathematics, but since real data will be collected – it will also deepen the understanding in physics or chemistry when sensors e.g. for pressure, temperature or pH are embedded.

Incorporating several connected devices creates the possibility for more dynamic interventions, more advanced classroom techniques, and even a modified role for teachers that is more focused on facilitating the work of learners through individual observation. By shifting processes and procedures to the background, the teacher has fewer responsibilities as an active ‘manager’– i.e. more time to craft a personalised learning experience. Contrary to many expectations, more technology could actually make education more human.

When teachers and learners work together, they can use tablets, smartphones or even VR helmets. They can even arrange a teaching-learning process remotely, using a webcam, internet connection, etc. This means that teachers can become liberated from managing classroom procedures and can focus on the learning activities more incisively in order to better contribute to personal and professional growth.

IoT is holistic in the sense that it operates like a system in which defined and interconnected topics interact with each other representing an organic whole. This iterative process guides learners to develop their inquiring minds and their computational thinking while practicing creativity.

Moreover IoT, besides providing general knowledge on STEM, is essential for introducing leaners to social science (e.g. public health, anthropology, archaeology, etc.), expanding their awareness and giving them practical lessons on how to use it.

Learn STEM is practical. Learners are actively engaged and learn through co-creation with others. IoT gives learners the freedom to make real-world experiences and observations through technology and by finding solutions to problems both independently and collaboratively. Practical exercises encourage learners to apply knowledge and practice skills and competences.

Such practical exercises engage learners since they are attracted to it, receive feedback and achieve immediate results. In this context, it is of high importance that learners have sufficient understanding of the tools they are being asked to be creative with. Thus, learners are allowed to meet in a collaborative environment to brainstorm ideas and document their work progress using technology.

Furthermore, IoT promotes the establishment of creative classrooms where learners are working directly on sensors or devices dealing with data quality, calibration, sensor failures and their reasons. Thus, they are more likely to express ideas, think outside the box, challenge problems with innovative solutions and most importantly - learn faster and more effectively.

Learn STEM is social. Current hype around IoT has focused largely on how connecting devices can create efficiency, but connecting people directly to digital networks may have the greatest potential to shift our social experience and even alter traditional institutions.

The way that school education supports teachers with the IoT in learning environments will significantly affect how we as a society function, communicate, collaborate, and move into a world of increasing interconnectedness. IoT is widely considered as the next step towards a digital society, where objects and people are interconnected and interact through communication networks. IoT has not only a considerable social impact, but will also revolutionise the working environment and industrial processes. On one hand, it will help to boost the competitiveness of European companies and, on the other hand, proficiency in this area will support the employability of people.

Furthermore, IoT is social because it fits perfectly to the following requirements:

- It provides customised learning;
- it enhances individual skills and competences;
- it helps to develop problem-based learning (e.g. face challenges and find solutions to everyday problems): learners are encouraged to ask questions in order to find the more appropriate answer to the problem they are investigating;
- it supports collaborative working;
- it increases emphasis on human diversities.

To conclude, it is crucial to apply **Learn STEM** for qualifying future professionals (secondary school students) able to support the digital transformation of European companies exploiting the advantages offered by IoT technology. Here, we can profit from the learners' experiences, knowledge and skills already gained in the past and build more knowledge, skills and competences through experiments and learning activities which are present in learners' daily life guaranteeing human interactions and emotional involvement.

4.2. Learn STEM Profile: Robotics

Developments in STEM are deeply rooted in today's challenges and at the same time intensely focus on the future. Education should guarantee that children and young people are given equal access to these STEM developments and are able to discover their passion and talent for STEM.

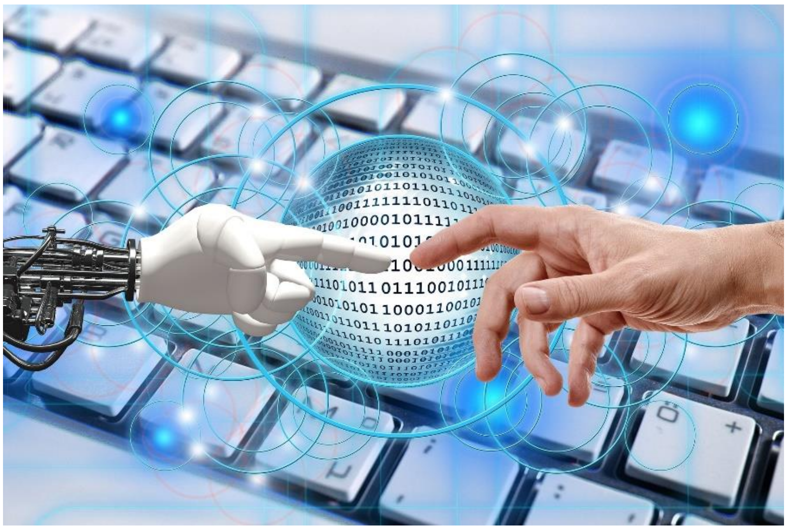


Figure 4: Robotics education prepares learners for the future

STEM education promotes science, technology, engineering and mathematics, but also the connection between these disciplines. It promotes thorough and critical reflection on social and scientific challenges, thus creating content at different classroom level and establishing partnerships.
Young people are born researchers: they are specialised in constantly exploring the world they live in. LearnSTEM acknowledges this natural urge and directs them towards deepening insights, and finally a potential STEM specialisation through a better learning prorcess and a customised career choice.

How does the Robotics link to STEM teaching and learning?

A first question to be answered is: What does robotics offer for educators and researchers? Robotics education provides learners with practical experiences for understanding mechanical and technological systems and languages. It helps to adapt to constant changes driven by the complex environment and to utilise knowledge in real-world situations across time, space, and contexts. In addition, along with the growing attention to STEM education, robotics has been suggested as an innovative solution. Regardless of the economic and social needs for new types of innovative and knowledgeable citizens, robotics can easily gain the attention of scholars as a means of empowering learners and providing authentic learning. By allowing learners to engage in these process-oriented learning experiences of robotics, learners can take initiative roles as co-constructors of learning, not as passive knowledge receivers or technology consumers.

Learn STEM is Complex. The STEM curriculum related to robotics established key ideas for each activity as target goal (e.g., the concept of robots, different types of sensors and actors, commands for programming, and programming concepts such as repeated loops and conditional branches). Robotics curricula can be categorised as follows: (1) concept (knowledge) domain; (2) practice (skills) domain and (3) attitude (disposition) domain.

Robotics education in the existing literature encompassed the crosscutting knowledge and skills in STEM areas such as subject-oriented knowledge (e.g. knowledge of physics) and cognitive skills (e.g. analysing, classifying and predicting). More specificially, in order to engage in robotics, users need understand robots (e.g., the different parts of robots and the function of the individual parts) as well as the entire system and software architecture of robots. In terms of application of knowledge, robotics provides the inherent advantage that it not only intensifies general knowledge, but rather allows the development of practical skills such as designing, constructing and operating robots.

Learn STEM is process-oriented. Learn STEM aims to engage learners in active learning and improve learning outcomes. This approach aligns with the knowledge building processes in STEM. Robotics can also focus on this process since it applies discursive, representational tools, such as modelling, movement, graphical visualisations, animations and a range of digital tools and resources that now pervade STEM professional and research practice.

Learners are encouraged to engage with the processes of investigation and problem solving, for example by identifying which type of material is suitable. Learners engage in mathematical/scientific reasoning and argumentation. They realise the importance of solid basic knowledge and they are further encouraged to develop an understanding of creative problem solving and design processes, like flowcharts, which help them to identify the next step in programming a robot. Learners are challenged and encouraged to develop their own arguments as means of explaining and justifying their understanding. A range of assessment tools are used to monitor and support the learning process of each learner or small groups.

Learn STEM is holistic. The STEM community is frequently required to integrate various disciplines. **Learn STEM** meets these developments and integrates the different STEM disciplines by evoking real-world problems. This shall stimulate learners' imaginative and collaborative problem solving and reasoning. Robotics can represent a tool since it is highly realistic.

STEM practice should incorporate knowledge of the individual disciplines as well as common knowledge across the disciplines. It is essential to acknowledge barriers and specialities of the individual disciplines, but further to demonstrate the generality of many phenomena and integrate this into a real-world learning strategy (see also: Vasquez 2014). Thus, **Learn STEM** focuses on STEM as a meta-discipline. This relates to the similarities among the various disciplines and refers to universal (or 'soft') skills that are common to all disciplines. **Learn STEM** incorporates interconnections between the individual practices of each discipline, recognising that by working on robotics, teachers can similarly represent the discursive practices of several STEM disciplines. Thus, barriers between disciplines can be broken down.

Learn STEM is practical. The practical nature of Robotics engages learners in critical and creative thinking, including understanding of interrelationships among systems. A systematic approach to experimenting, problem-solving, prototyping and evaluating introduces the value of planning and reviewing processes to realise ideas. It is not simply a computing problem but includes real interaction with robots and allows a direct feedback to the learner.

Through the practical application of various methods including digital technologies, but also physical sensors, learners develop skills and coordination through experiential activities. This will help to strengthen motivation of young people and engage them in a range of learning experiences that are transferable to other fields such as family and home, constructive leisure activities or community contributions.

Learn STEM is social. All learners are encouraged to develop action capability and a critical appreciation of the processes by which technologies are developed and how technologies can contribute to societies. Learners can get opportunities to consider the use and impact of technological solutions on equity, ethics and personal and social values.

For instance, robots can be programmed to assist children or elderly people. In creating such solutions, as well as responding to other societal demands, learners learn to consider desirable and sustainable living standards and to reflect technological effects. This rationale is extended and complemented by specific rationales for each technology subject. Robotics enables learners to become creative and responsive designers. By considering ethical, legal, aesthetic and functional factors as well as the economic, environmental and social impacts of technological changes learners develop the knowledge, understanding and skills to become discerning decision-makers in future.

In robotics learners manage their projects rather independently and collaboratively from conception to realisation. They apply design and systems thinking and design processes to investigate, generate and refine ideas, as well as to plan, produce and evaluate solutions. Since the results is rather obvious they can easily develop a sense of pride, satisfaction and enjoyment from their increasing ability to develop new systems.

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Annex 1: Examples of Innovative STEM Learning

This collection provides some examples of good practices for teaching Science, Technology, Engineering and Mathematics (STEM) through innovative pedagogical approaches. Furthermore, we address specific examples to follow for teaching STEM in the **Inquiry Learning Package**.

	Example 1
Title/Name of the example	Eratosthenes Experiment
Organization, country and website	Inspiring Science Education: http://www.inspiring-science-education.net/showcases/eratosthenes-experiment http://portal.opendiscoveryspace.eu/en/community/eratosthenes-experiment-2015-820309 http://tools.inspiringscience.eu/delivery/view/index.html?id=ccb0d6e2559b4c9586e3ec8d615b3294&t=p http://portal.opendiscoveryspace.eu/en/edu-object/eratosthenes-experimenthighschool-820142
Brief description (abstract)	Eratosthenes Experiment for the Measurement of the Earth's Circumference The Eratosthenes Experiment calculates the circumference of the Earth by using eLearning educational tools and simple instruments, repeating the experiment of the Greek mathematician, Eratosthenes (276 BC-194 BC). This experiment enabled Eratosthenes to prove the sphericity of the Earth and to measure its circumference. Full set of learning materials, online tools and tutorials for school teachers and learners. Two schools on the same longitude have to collaborate and to measure the shadow of a stick of 1 m in length.
Age range	12 to 18
Subject/discipline or cross-disciplinary?	cross-disciplinary
Name of providing Learn STEM partner	OUNL

	Example 2
Title/Name of the example	Babies and the moon
Organization, country and website	Inspiring Science Education http://portal.opendiscoveryspace.eu/de/node/842060 http://tools.inspiringscience.eu/delivery/view/index.html?id=7f2bf9a66db44f8cb9552cb58df17243&t=p
Brief description (abstract)	This STEM lesson intends to explore misconceptions related to the moon.
Age range	6 to 14
Subject/discipline or cross-disciplinary?	cross-disciplinary
Name of providing Learn STEM partner	OUNL

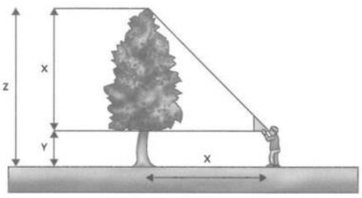
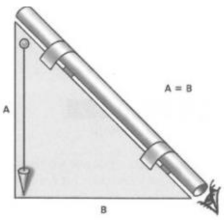
	Example 3
Title/Name of the example	Star in the Box
Organization, country and website	Inspiring Science Education http://portal.opendiscoveryspace.eu/en/community/star-box-828460 http://tools.inspiringscience.eu/delivery/view/index.html?id=17e60cf0613e40f4be3f014b4fb7e2ca&t=p
Brief description (abstract)	Star In A Box offers a lesson plan for one- or two-hour sessions using the highly interactive Star In A Box application. This App simulates the evolutionary stages of stars of various masses. Learners can follow changes in temperature, pressure and size for various stars. Sample questions of various difficulties are provided. Learners will learn about the way stars are detected from Earth, about types of stars (i.e. stars of different masses) and about how this affects their lifecycles as well as learn about stellar evolution using the Hertzsprung-Russel diagram. This lesson plan aims to support physics and astronomy qualifications.
Age range	14 to 18
Subject/discipline or cross-disciplinary?	cross-disciplinary
Name of providing Learn STEM partner	OUNL

	Example 4
Title/Name of the example	Formula 1 in schools (v.3)
Organization, country and website	Inspiring Science Education http://tools.inspiringscience.eu/delivery/view/index.html?id=249054780c41462eb4e9efa50a750312&t=p
Brief description (abstract)	The F1 in schools is a worldwide multi-disciplinary challenge and one of the largest educational initiative promoting Science, Technology, Engineering and Mathematics (STEM). It is now in its 15th year of operation and has expanded across the world operating in over 30 countries. Learners form a team of three to six members and are commissioned to design, construct and race a small scale Formula One car made from F1 model block and powered by compressed air cylinders. Furthermore, teams must prepare a pit display, interviews, oral presentation and a 20 page portfolio showcasing their work. Sponsorship must be gathered and collaborations formed. Another important requirement of this competition is innovation. Some main examples of F1 in school innovations will be discussed in this demo. Teams are also given the opportunity to compete regionally, nationally and internationally for the F1 Schools World Championship trophy. Since the demonstrator could cover more than one didactical unit, this example (one didactical unit) was selected for the needs of advanced level teams qualified to compete at region al and national finals. The lite version of Logger Pro ISE Tool will be used for analysing the average speed data of F1 in schools team cars.
Age range	9 to 19
Subject/discipline or cross-disciplinary?	cross-disciplinary
Name of providing Learn STEM partner	OUNL

	Example 5
Title/Name of the example	Increase your swimming pool experience
Organization, country and website	Katholieke Scholengroep RHIZO vzw Burgemeester Nolfstraat 39, 8500 Kortrijk Flanders - Belgium www.rhizo.be www.designyourcity.be
Brief description (abstract)	Taking a swim in the local swimming pool, can sometimes be a bit boring or disappointing. – Learners identify what aspects of the swimming pool may be annoying by investigating, interviewing and analysing the obtained data. – Learners discuss the problem, brainstorm and collect ideas to select several possible solutions. – Afterwards they do test runs and produce a prototype. – This prototype is presented to the management of the swimming pool.
Age range	12-14
Subject/discipline or cross-disciplinary?	Design thinking as a method of STEM didactis
Name of providing Learn STEM partner	Eekhout Academy

	Example 6
Title/Name of the example	A water-driven lifting crane
Organization, country and website	STEM tornooi (Flemish Technology and STEM Competition) Flanders - Belgium www.technologieolympiade.be/vto/index.php?request =stemtornooi/index
Brief description (abstract)	The company Aquatech is located next to the river Schelde. This is of course the ideal location to transport as many goods as possible by waterway. To do so, the company uses small containers and smaller ships for freight transport. Aquatech has no place and money for huge cranes to load the small containers onto the ships. How can they bring the load of five containers on board? Designing a water-driven crane would be an additional challenge. We use no electricity, no motors, but only water to set the crane in motion. – Learners are challenged to make a preliminary study of this project and produce a scale model of the crane. – Different aspects of STEM assignments are possible: ○ How will the crane move? ○ What movements will the crane have to perform? ○ What are the basic principles of hydraulics and how can we apply them in our project? ○ What is the size, weight and shape of the containers to be moved? ○ How can we best lift the containers? ○ How are we going to manage the task?
Age range	12-14
Subject/discipline or cross-disciplinary?	Principles of mechanics and hydraulics
Name of providing Learn STEM partner	Eekhout Academy

	Example 7
Title/Name of the example	Paris Dakar Ramp Jump Challenge
Organization, country and website	SIBE Sportlaan 4, 8300 Knokke-Heist Flanders - Belgium http://sibe.be
Brief description (abstract)	In the Paris-Dakar ralley, cars have to bridge gaps in the sand surface. To practise this manoeuvre, the ralley pilots use slopes or ramps. How can we help those pilots with the construction of such a ramp? – After looking at a number of movies of cars and skiers jumping from a ramp (succeeding and failing), learners brainstorm in groups about how to design this ramp. – Research - design – study of material. – Construction of the ramp of max. 1.5 m which you can bridge a minimum distance of 1 m. – Design a car (or vehicle: it can also be a tricycle) that can bridge this distance and ends up on all its wheels. – Presentation of the structure (ramp and car) and the result of your jump by oral presentation, movie or didactic material. – Reflection at the end of the project: Explain what problems you encountered during this project and how you solved them.
Age range	12-14
Subject/discipline or cross-disciplinary?	Physics and mathematics - movement and friction - calculation of angles - balance - bridge the distance - gravity and centre of gravity - surface, aerodynamics ...
Name of providing Learn STEM partner	Eekhout Academy

	Example 8
Title/Name of the example	Find and measure the highest tree in the woods
Organization, country and website	Sint-Andreaslyceum Sint-Kruis Fortuinstraat 29, 8310 Sint-Kruis Flanders – Belgium http://humaniora.sask.be
Brief description (abstract)	To renew the ridge of an old farm, the building company wants to replace the central beam. How can we find the tree that has the minimum required dimensions? How can we build a tool to measure the height of a tree?   Find out what kind of tree is the tallest. Why is this tree taller than the others?
Age range	14-16
Subject/discipline or cross-disciplinary?	Engineering, Math, Natural Science
Name of providing Learn STEM partner	Eekhout Academy

	Example 9
Title/Name of the example	Educational activities in STEM (STEAM) days
Organization, country and website	Engineering Lyceum of Kaunas University of Technology (KUT), Kaunas, Lithuania www.inzinerijoslicejus.ktu.edu/inzinerija/inzinerine-veikla
Brief description (abstract)	Numerous options for STEM activities: 1. Learners take part in the STEAM profile events, organised by the educational institution. One of them is **“STEAM DAY”**: During the event, engineering issues are discussed, experiments at the laboratories are realised, lectures and workshops are done and all the topics are related to STEM. Learners participate in many educational activities at Kaunas University of Technology and in other various science and business institutions. 2. At the **“Engineer's Day”**, learners visit various institutions dealing with engineering topic (for example an aviation museum) and participate in specific educational programs, for example "Why do planes fly?". During these trips, learners get know more about the engineering constructions, particular techniques, learn about specific engineering equipment, can visit museum expositions etc. 3. **Design Week**: exhibitions of learners' engineering projects are organised and displayed as interactive exhibitions. The event stimulates interest in the possibilities of contemporary media art expression, engineering, communication and technology synergy. 4. Learners **visit the KUT laboratories**, for example: visiting Faculty of Chemistry, where they are introduced to various research, food production and the process of creating new recipes. Learners also learn how food industry specialists are trained, what kind of knowledge students get, how much they learn and what they do to get the successful job after finishing their degrees. 5. **Trips to engineering profile factories**: learners attend and visit the company's workshops, where they get acquainted with engineering, automated production lines and practically get acquainted with the peculiarities of technologies used in modern construction products.
Age range	7-18
Subject/discipline or cross-disciplinary?	Crossdisciplinary: engineering, ICT, chemistry, technology, design
Name of providing Learn STEM partner	Kaunas Science and Technology Park, Lithuania

	Example 10
Title/Name of the example	Engineering Educational Program for pupils
Organization, country and website	VGTU Engineering Lyceum, Vilnius, Lithuania, (Engineering lyceum of Vilnius Gediminas Technical University) http://www.vgtulicejus.lt/inzinerija/inzinerinis-ugdymas/
Brief description (abstract)	Up to 25% of the content of the engineering discipline is integrated into the programs at the VGTU engineering lyceum. The aim is to present a comprehensive picture of the world to learners and to develop their ability to combine engineering and general competences in school. More than 75% of engineering educational programs are directed towards the practical application of knowledge and technology, creative work, project implementation, technological process, management and design, as well as presentation of work and learners' future career planning Engineering Educational Program: learners are trained in 3 block lessons (lectures and practice) taking place at VGTU Sunrise valley (Science and Technology Park) in: construction, mechanics and design. All blocks consist of two to three academic hours, then learner carry out two to three laboratory exercises. Learners attend a 12-14 hour engineering course after which consultants discuss contents with leaners and learners write their reports. Learners participate in design lessons, practical design and graphics. The program is implemented by subject teachers and university lecturers.
Age range	15-17
Subject/discipline or cross-disciplinary?	Crossdisciplinary: Design, mechanics, construction
Name of providing Learn STEM partner	Kaunas Science and Technology Park, Lithuania

	Example 11
Title/Name of the example	Robotic Academy and Robotic camps
Organization, country and website	VGTU Engineering Lyceum, Vilnius, Lithuania, (Engineering lyceum of Vilnius Gediminas technical university) http://www.vgtu.lt/norintiems-studijuoti/moksleiviams/robotikos-akademijos-stovyklos-moksleiviams-ir-ne-tik/447?nid=94884
Brief description (abstract)	The main goal of the Robotic Academy is to teach learners- so called *little inventors*, that learning is a lifelong process and that the best investment is always in their knowledge and experience. For the inventors of classes 1- 8 all years are intended to reveal the power and practical simplicity of mathematics. Learners are introduced to the world's most relevant competences of STEM. Also, this this academy explains the many mathematical bases and practical applications of the theory based on the examples of the most popular computer games (Minecraft, League of Legends, Overwatch, Battlefield). Tasks and constructions of these games are used and applied. All competences are interpreted through the prism of mathematics and robotics. At the academy, the mathematical knowledge gained during school lessons is consolidated and used in practical tasks with robots by designing, programming and testing. During the class, learners deal with real-world problems, developing quick-prototype solutions for problems, problem-solving experiments and discuss results. They develop all the STEM competences, discovering their strongest side. Programs are prepared on the basis of **LEGO Education** methodologies acquired by the Robotics Academy's experience in non-formal education and meet the requirements of formal education.
Age range	7-14
Subject/discipline or cross-disciplinary?	Robotics (engineering)
Name of providing Learn STEM partner	Kaunas Science and Technology Park, Lithuania

	Example 12
Title/Name of the example	'Festival Nacional de Robótica' Portuguese Robotics Festival
Organization, country and website	Organisers vary from year to year. In 2017, the University of Coimbra was responsible: www.uc.pt http://robotica2017.isr.uc.pt This nationwide event is sponsored by several institutional partners (public and private) as well as the Institute of Electrical and Electronics Engineers (IEEE).
Brief description (abstract)	This competition is supported by many schools throughout the country, namely via the action of their respective robotics clubs. There are four different topics for the competitions which take place at one location (Coimbra in April 2017), that is: • OnStage Junior: robots dance following the music; • Futebol Junior: football tournament with small teams composed of two robots, a game table and a human referee (comprises three sub-groups, according to the age of learners); • Resgate Junior: learners are separated by age, thus forming several sub-groups for this topic. The goal is to program a robot which is going to fulfil a rescue mission autonomously in a field full of obstacles and danger; • FreeBots Junior: challenges learners from primary, secondary and vocational schools to present the robots they have developed (with innovative features) in a technical and public demonstration. This includes physical robots (one or more), mobile or otherwise, terrestrial, aquatic or aerial.
Age range	8-19
Subject/discipline or cross-disciplinary?	Cross-disciplinary: mathematics, programming, mechanical engineering and robotics
Name of providing Learn STEM partner	Madan Parque

	Example 13
Title/Name of the example	The Young Engineer School (at the VGTU Lyceum) and Technical creativity classes “Future engineering”
Organization, country and website	VGTU Engineering Lyceum, Vilnius, Lithuania, (Vilnius Gediminas Technical University) The Young Engineer School (academy) http://www.vgtu.lt/norintiems-studijuoti/moksleiviams/jaunojo-inzinieriaus-mokykla/449
Brief description (abstract)	The Young Engineer School is a free academy that is founded at the VGTU Lyceum and provides informal lessons. Learners are provided with free thematical lectures of STEM disciplines. Professors, associate professors and lecturers provide a comprehensive introduction to the study programs, prospects of obtaining a diploma, career opportunities, etc. After receiving more than five lectures, the Young Engineer certificate is given. Lectures and workshops thematics: Design, architecture, aircraft engineering, biomechanics, robotics, safety engineering during emergency situations, construction business and the application of the latest ICT technologies.
Age range	15–18
Subject/discipline or cross-disciplinary?	Mathematics, ICT, engineering
Name of providing Learn STEM partner	Kaunas Science and Technology Park, Lithuania

	Example 14
Title/Name of the example	Robotics
Organization, country and website	Education Development Centre For more information: https://sciencemarch.eu
Brief description (abstract)	Programming and development of robots is getting more and more popular in Lithuania each year. However these activities are mostly related to informal education (for example: http://www.robotiada.lt/apie-varzybas) or projects (http://patinka.infobalt.lt/). Lithuania is planning to include robotics' modules in general education curricula. Further information: Robotics academy: http://www.robotikosakademija.lt/ Robotics competition: http://www.robotiada.lt/ Website of robotics competition organizers: http://patinka.infobalt.lt/
Age range	11-19
Subject/discipline or cross-disciplinary?	Cross-disciplinary. Robotics encourages creativity, independence, persistence and curiosity in innovations in each learner. It develops communication and collaborative work skills.
Name of providing Learn STEM partner	KSDP

	Example 15
Title/Name of the example	ICT school
Organization, country and website	VGTU Engineering Lyceum, Vilnius, Lithuania, (Vilnius Gediminas technical university) http://www.vgtu.lt/norintiems-studijuoti/moksleiviams/vgtu-it-mokykla/232860
Brief description (abstract)	Vilnius Gediminas Technical University (VGTU) IT School invites learners to courses on information technologies i.e. programming of web pages, combining design elements, working on the latest project management techniques and using electronics and mechanics laboratories. During lectures, different technologies and their applications are tailored according to the individual needs of the learner. The lectures are held at modern workshops of the VGTU Creativity and Innovation Centre and also at the Sunrise Valley (Science and Technology Park). Students learn together with the most advanced specialists in their field at one of the strongest Lithuanian Technology Universities.
Age range	11–14
Subject/discipline or cross-disciplinary?	Informal education: ICT
Name of providing Learn STEM partner	Kaunas Science and Technology Park, Lithuania

	Example 16
Title/Name of the example	3D printers
Organization, country and website	'MARCH' EU funded project Education Development Centre (EDC) https://sciencemarch.eu/index.php/best-practices-mnu-uk https://sciencemarch.eu/images/sm-images/bp/Lithuania_3DPrinters.pdf
Brief description (abstract)	3D printers open up wide possibilities in education. 3D printers give a new perspective on learning and teaching common subjects: mathematics, technologies, drawing, arts. This practice is particularly related to the surrounding environment and is gaining popularity in various industry branches. Further information: Methodical material: http://www.upc.smm.lt/ekspertavimas/mddb/Informacin%C4%97s%20technologijos/Autodesk%20123%20-%203D%20grafika.pdf Additional seminars to guide teachers and learners: http://www.upc.smm.lt/naujienos/stem/3d.php
Age range	11–19
Subject/discipline or cross-disciplinary?	Cross-disciplinary: mathematics, technologies, drawing, arts
Name of providing Learn STEM partner	Effebi Association, KSDP

	Example 17
Title/Name of the example	STEM Learning - Activity Case Studies
Organization, country and website	STEMNET (https://www.stem.org.uk) https://www.stem.org.uk/resources/collection/3035/activity-case-studies (registration data needed)
Brief description (abstract)	A collection of STEMNET case studies which profiles activities completed by STEM ambassadors. These activity case studies include a set of career case studies which describe job positions of STEM ambassadors who lead the activities. STEM ambassadors are volunteers of all ages working in a range of STEM-related roles from apprentice engineers to geologists and nuclear physicists to zoologists.
Age range	11−19
Subject/discipline or cross-disciplinary?	Cross-disciplinary: Careers, Design and technology, Engineering, Mathematics, Science
Name of providing Learn STEM partner	Effebi Association

	Example 18
Title/Name of the example	"Euston, we have a problem...to solve!" Abstract from *Working together:Making STEM happen in secondary schools*, available online at: https://wellcome.ac.uk/sites/default/files/making-stem-happen-in-secondary-schools-wellcome-2012.pdf
Organization, country and website	Wellcome Trust, charity registered in England and Wales (https://wellcome.ac.uk/)
Brief description (abstract)	As part of 'Enginuity', a dedicated STEM creativity week, students at South Camden Community School in Euston designed and built kites to help them understand the principles of flying. Participants tested and adapted their designs before competing in a timed flight trial to discover whose prototype worked best. As in other successful STEM activities, learners' enjoyment was improved by involving experts and using clear parameters. This project also drew on the school's cultural diversity by looking at the worldwide enthusiasm for kite flying. (From pages 20–21: https://wellcome.ac.uk/sites/default/files/making-stem-happen-in-secondary-schools-wellcome-2012.pdf)
Age range	Not specified
Subject/discipline or cross-disciplinary?	Subject: aircraft design
Name of providing Learn STEM partner	Effebi Association

	Example 19
Title/Name of the example	School of the “2nd educational way” Dahme Spreewald, Germany External lab courses on biology
Organization, country and website	Schule des Zweiten Bildungsweges Landkreis Dahme Spreewald (this school provides university entrance degrees for learners who failed the general school system) www.zbw-lds.de/index.php?option=com_content&view=article&id=96&Itemid=102&limitstart=2
Brief description (abstract)	Visits of external school labs are an essential part of the concept of this school for the natural sciences. At the “Gläsernes Labor” of the Max Delbrück Centre in Berlin-Buch, learners perform experiments working with DNA. They start by extracting DNA from saliva and separate different DNA fragments in a gel electrophoresis. Learners learn about staining of DNA to make the DNA sequences visible. They are introduced into the principles of “genetic fingerprinting” in order to identify persons. They further get introduced to general biological work practice, i.e. using a pipette, centrifuge and electrophoresis.
Age range	18–24
Subject/discipline or cross-disciplinary?	Biology – Lab practice as part of STEM didactis
Name of providing Learn STEM partner	TUASW

	Example 20
Title/Name of the example	Youth Research Centre (Jugendforscherzentrum)
Organization, country and website	Paul Dessau Gesamtschule Zeuthen, Germany www.gesamtschule-zeuthen.de/index.php/forschung/jugend-forscht
Brief description (abstract)	The school has founded a ‘research centre’ to coordinate youth research activities in collaboration with scientific institutions. Project ideas can come from learners, teachers or research institutions, but the activities are performed by the learners themselves. This project establishes and consolidates contact between learners and scientists. In collaboration with the TUAS Wildau, learners devolped a lactose sensor which can quantitatively measure lactose concentrations e.g. in milk. Here, learners need to combine knowledge about chemistry, physics and biology to set up a fully functional system. They take part in regional and national competitions with their inventions and learn to explain and demonstrate their ideas and results to the public.
Age range	16–19
Subject/discipline or cross-disciplinary?	Biology (as well as chemistry and physics) Establishment of work timeline and evaluation of success Development of team work capabilities
Name of providing Learn STEM partner	TUASW

	Example 21
Title/Name of the example	MINT-EC National excellence school network, Germany
Organization, country and website	Network of schools that aims to provide excellence in STEM learning https://www.mint-ec.de
Brief description (abstract)	STEM education as part of a comprehensive education (in German STEM corresponds to 'MINT'): - preparation of learners for the future in economy, science and society - development of specific STEM interests - introduction to professional careers - endorsement of interested learners - cooperation among schools - cooperation with scientific institutions and companies - information and motivation to enrol for a STEM study course at universities - workshops, camps, competitions, school slams and courses for teachers - literature resources for teachers to develop STEM courses
Age range	11–19
Subject/discipline or cross-disciplinary?	mathematics, informatics, natural sciences and engineering
Name of providing Learn STEM partner	TUASW

	Example 22
Title/Name of the example	'STEM Toys'
Organization, country and website	Science4You (private company) https://brinquedos.science4you.pt/38-stem
Brief description (abstract)	STEM toys helps children to stimulate their cognitive abilities in these areas while they play. Toys like scientific kits, puzzles, quizes and logic games are great tools to develop logical and critical thinking, stimulate curiosity and become more aware of the world around them. The company Science4you believes in innovation and is always looking for new trends in educational toys. Science4you promotes STEM systems as a way to stimulate knowledge through practical experiences. Science4you has a team of experts who work on the development of toys to supply children with learning tools focused on STEM interests and prepare them for their future.
Age range	all ages
Subject/discipline or cross-disciplinary?	Cross-disciplinary
Name of providing Learn STEM partner	Madan Parque

	Example 23
Title/Name of the example	Theatre sports
Organization, country and website	Education Development Centre For more information you can visit our website: https://sciencemarch.eu
Brief description (abstract)	Threatre sports encourages theatre improvisation. It aims to create groups' narrative to focus on the present without preparing or contemplating for activities. Improvisation encourages competitiveness. Humor is essential in theatre sports. Activities in theatre sports require courage, use humor to express feelings, emotions and to have no prejudice. It encourages participants to combine different experiences and transfer them to new situations. Theatre sports aims to release creative forces, relax, 'switch-off' their minds and surrender to creativity. Professional actors use sports to relax, build a team and activate their subconsciousness. The same objectives can be achieved in this education process. It could be applied to various educational environments without additional equipment needed. It enables to form informal/closer ties between teacher and learner. Theatre sports could be used to reveal creativity, communication skills and develop general competences. Further information: Lecture by ZilvinasBeniusis: 'Theatre sports: release imagination': https://youtu.be/DRFv9miQFew Comments on theatre sports: https://youtu.be/2YEjTU_YD4U (start at 1:18 min. and turn on EN subtitles)
Age range	11–19
Subject/discipline or cross-disciplinary?	Cross-disciplinary
Name of providing Learn STEM partner	KSDP

	Example 24
Title/Name of the example	MakerKlas
Organization, country and website	Qeske, Netherlands, www.qeske.nl, www.makerklas.nl
Brief description (abstract)	MakerSpace is a field lab where people can explore, research, invent, make, learn, share all kind of ideas about high technolgy and low technology.
Age range	10–99
Subject/discipline or cross-disciplinary?	Cross-disciplinary
Name of providing Learn STEM partner	Agora

	Example 25
Title/Name of the example	Agile Learning
Organization, country and website	Niekée / Agora Roermond, The Netherlands: www.agoraroermond.nl / www.niekee.nl
Brief description (abstract)	Agile Learning process supports the way of learning where learners explore their own curiosity. The process of learning can be visualised by using Scrum. Learners lead and own their learning process. The role of the teacher is coach. Field experts are available when needed. Agile Learning promotes student's self-regulation and the possibility to be flexible in taking the next steps. Entrepreneurship is one of the effects we observe for this type of learning. Learners develop innovative skills (collaboration, critical thinking, creativity and communication).
Age range	12–18
Subject/discipline or cross-disciplinary?	Cross-discplinary
Name of providing Learn STEM partner	Niekée

	Example 26
Title/Name of the example	Agile Learning
Organization, country and website	Agrupamento de Escolas de Portela e Moscavide, Portugal http://agepm.pt/cms/ https://www.facebook.com/groups/orobotajuda
Brief description (abstract)	Using robots as an educational help to encourage learners' curiosity towards the discovery and learning of basic concepts within physics and chemistry, mathematics and computers. Planning and presentation of experimental activities by and for students stimulates and promotes interest in STEM and self-learning. By using robots we intend to draw young people's attention to activities related to science, particularly to engineering and information technologies. Therefore, learners in the school plan and build prototypes to solve specific problems.
Age range	8−18
Subject/discipline or cross-disciplinary?	Maths, physics, programming, robotics
Name of providing Learn STEM partner	Agrupamento de Escolas Emídio Navarro - PORTUGAL

	Example 27
Title/Name of the example	The Inventors
Organization, country and website	The Inventors, Portugal http://www.theinventors.io
Brief description (abstract)	The Inventors develops educational kits and classes that aim to inspire a new generation of inventors. These include projects around coding, electronics, design, game creation, animation and other creative subjects.
Age range	7–14
Subject/discipline or cross-disciplinary?	Cross-disciplinary: technology and creative subjects
Name of providing Learn STEM partner	Agrupamento de Escolas Emídio Navarro - PORTUGAL

Annex 2: Mapping of STEM Stakeholders in Europe

In the following the stakeholders which are involved in STEM education are collected for the different countries partnering in the LearnSTEM project.

Name of Learn STEM partner: Eekhout Academy
Country of Learn STEM partner: Flanders - Belgium

Name of key stakeholder	Impact on STEM teaching in learning situations
Flemish Ministry Education	The Flemish Ministry of Education determines the minimum and attainment goals that schools have to achieve in order to be recognised and funded.
Schoolboard of Board of Governors	The School Boards have the legal power to develop the curricula for their own school. This board decides on the school policy (such as: implementation of STEM) and the appointment of school management.
Education Networks	The power to develop curricula is mandated to the large Education Networks that historically grew as schools joined forces. The education networks are responsible for the content of the curricula. The school inspection checks if all the minimum and attainment goals are integrated in those curricula.
University Applied Sciences – Initial Teacher Training Department	The UAS offer initial teaching training programmes that now include also STEM teaching.
University - Science and Engineering Departments	The universities offer an academic teacher training programme that is followed by a master's degree in science and engineering. Recently, a STEM module was added to these programmes.
Pedagogical Advisory Body (Pedagogische begeleidingsdienst)	The Flemish Ministry of Education organises the pedagogical support of the schools through the Pedagogical Advisory Body. The pedagogical advisors will counsel and guide the school management and teachers. One of their tasks is to support the implementation of STEM.
Organisations for teacher's CPD/IST: Continuous Professional Development / In-service Training	CPD and IST organisation (such as Eekhout Academy) will offer teacher training on various pedagogical and didactical subjects. One major focus is teacher training on STEM.
School Management	School management will take responsibility for the development of school policy, vision and mission on STEM.

	Furthermore, the management has to take care of the conditions that allow a good STEM teaching (infrastructure, student evaluation policy, recruitement of teachers, teacher professionalisation…)
Departmental team of STEM teachers	The departmental team of STEM teachers has to implement the school policy and agree on all practical aspects involved in STEM teaching. They can develop STEM lesons or STEM challenges.
Individual Teacher	The individual teacher has the very important job to create the needed pedagogical and didactical atmosphere in the class room in order to allow STEM methodology. The teacher has direct influence on the STEM process during the teaching.

Name of Learn STEM partner: Kaunas Science and Technology Park
Country of Learn STEM partner: Lithuania

Name of key stakeholder	**Impact on STEM teaching in learning situations**
Ministry of Education and Science, Vilnius, Lithuania	The aim of this institution in Lithuania is to implement the national system of formal and non-formal education which secures social attitudes in favour of education and creates conditions for lifelong learning in a changing democratic society. Moreover, the aim is to implement the state policy of science and studies in accordance with the Law on Science and Studies and other legal acts. It also has to coordinate the activity of Lithuanian institutions of science and studies, etc. The impact of the Learn STEM project may be essential as the new pedagogical models can be introducd to this institution and discussed as new and relevant theories. It may change some of the programmes of teaching methods and programmes of STEM and can improve higher education studies profile as well. The development and application of new STEM pedagogical models allow the Ministry of Education and Science to improve educational programmes related to STEM.
STEM profile schools: Engineering Lyceum of Kaunas University of Technology (Kaunas), and Engineering Lyceum of Vilnius Gediminas Technical University (Vilnius) and other technology profile gymnasiums and schools in Lithuania	Both Lithuanian technology profile lyceums (KUT and VGTU) would benefit from the Learn STEM project. The schools would take good practices described in the project, new methodologies and teaching programmes will be integrated and strengthen STEM subjects in schools. Results may help to implement new methods in collaboration between schools and universities, may help to improve access to laboratories, create new research, etc. Integration of STEM principles into all grades would be very valuable, would improve teaching programmees and promote the non-formal learning of learners' STEM education.
Education Development Centre (EDC), Vilnius, Lithuania	The Education Development Centre (EDC) is the largest institution affiliate to the Ministry of Education and Science of the Republic of Lithuania providing educational support for pre-school, primary and general education. EDC staff consists of more than 100 professionals in education.

	The aim of this Centre is : • to formulate a general education curriculum which corresponds to the needs of society; • to initiate, create and implement innovations in education; • to implement education content quality assurance; • to improve school performance**;** • to implement necessary quality assurance activities through in-service teacher training and initiate and implement in-service teacher training programmes. The impact of Learn STEM can improve all those activities, related to STEM education programmes, implement better teacher training in STEM and improve school performance in STEM subjects. The aim is to upgrade and create more innovations in STEM learning, to implement innovations in pedagogical programmes and to ensure better quality of pre-schools related to STEM. STEM pedagogical models would also be beneficial for creating a new pedagogical model in Lithuania and to improve current systems.
Kaunas University of Technology (KUT) , Kaunas, Lithuania and Vilnius Gediminas Technical University (VGTU) (Vilnius)	The benefits of the Learn STEAM project: new methods and good practices for technological universities could be applied and used. KUT and VGTU, located in the two largest Lithuanian cities, would be interested in the results of STEM learning new methodologies and principles. It will help to encourage cooperation between schools and universities within the framework of STEM. This would allow universities to tailor specific training programmes for learners, invite learners to lectures/laboratory exercises, present STEM subjects in workshops, introduce the practical nature of STEM subjects and enable STEM subjects to be taught more efficiently.

Regional STEAM centre, Lithuania	Ten interactive science centres for pupils (STEAM centres) will be created until the end of 2020 in ten different Lithuanian regions. These centres will increase the innovation culture in Lithuania. In order to increase learners' interest in STEM, ten STEAM centres will respond to the specifics and needs for innovation of each region. These centres will allow children to get acquainted to STEAM, the latest technologies, learn to make research, and do experiments. In the new STEAM centres, the students will work together with postgraduate students, lecturers, business representatives. Here, learners can prepare for their future careers in STEAM profile studies. STEAM centres will also provide opportunities for teachers to improve their qualifications and public access to research and innovation. The centres are still in the process of development. Thus, the new pedagogical methods of Learn STEM can be utilised during the development process. Centres can take the most effective and innovative methods from the good practices of the Learn STEM project and incorporate them into their activities.

Name of Learn STEM partner: **Effebi Association**
Country of Learn STEM partner: **Italy**

Name of key stakeholder	**Impact on STEM teaching in learning situations**
Municipality	Promoting workshops and meetings to encourage learners to approach technical-scientific subjects
Policy maker	Exploring the numerous opportunities and skills that STEM careers offer
Associations/Foundations/NGOs	Supporting the female role in an increasingly extended scientific world
Organisations	Fostering more women in science
Ministry of Education in collaboration with the Department of Equal Opportunities of the Council Presidency	The month of STEM: http://ischool.startupitalia.eu/sociale/40566-20160212-ragazze-step-pari-opportunita: from 8th of March until 8th of April: promoting innovation and science in schools, beyond gender stereotypes.
Department of Equal Opportunities of the Council Presidency	Organising courses and summer camps to promote studying and lifelong learning of science and technology
Professionals working within the technical-scientific field	Raising awareness among learners and teachers about STEM careers
Teachers	Training available with online free courses through ‘*STEM & MOOCs*’ platform
Parents	Involvement in creative workshop activities
Students	Sharing of educational material and activities

Name of Learn STEM partner: **NAWITEX School Labs – Technical University of Applied Sciences Wildau, Germany**

Country of Learn STEM partner: **Germany**

Name of key stakeholder	**Impact on STEM teaching in learning situations**
Ministries of Education of the 16 different States of Germany	Education is regulated by the individual states of Germany. Thus, every state has a slightly different school systems and curricula. The 'Kultusministerfonferenz' which comprises all the Ministers of the German states defines general standards for the different school types. The 'bildungsserver' of the states comprises the essential aspects of the curricula: https://www.bildungsserver.de//Die-Landesbildungsserver-450-de.html
State Institutes for Education	Most states have installed State Institutes (Landesinstitute) which are dealing with the development and implementation of the curricula
School management	The school management will take responsibility for the development of the school system. It will define the profile of the school (e.g. arts, music, languages, maths, natural sciences, STEM….), develop visions and establish cooperations. Furthermore, management is also responsible for the conditions that allow a good STEM teaching (infrastructure, student evaluation policy, recruitement of teachers, teacher professionalisation…)
Team of mathematics or physics or chemistry or biology teachers	The team of teachers for the individual areas of STEM (or combined ones) has to implement the school policy and organise the practical aspects involved in STEM teaching.

Name of Learn STEM partner: **MADAN PARQUE**
Country of Learn STEM partner: **Portugal**

Name of key stakeholder	**Impact on STEM teaching in learning situations**
FCT NOVA	FCT NOVA stands for Faculty of Sciences and Technology of NOVA University of Lisbon, the most important stakeholder for Madan Parque. Their curricular offer is exclusively for science and engineering. Thus, outcomes of the Learn STEM project are also relevant for the concerned stakeholder, eager to promote enrolment of STEM students for master courses.
ATEC – Training Academy	ATEC is a training academy closely interlinked to AutoEuropa which is the manufacturer of Volkswagen SUV in Portugal. This training academy offers a wide range of courses for the professional qualification of unemployed youth and adults. Moreover, this academy offers a variety of technical courses for learners starting at 9th grade (apprenticeship available for learners under 25 years of age, education and training of adults, if age >23). Their offer consists also of technological specialisation courses addressed to learners attending 12th grade.
Escola Profissional de Educação para o Desenvolvimento (EPED)	EPED is a vocational school located at Caparica, next to the premises of Madan Parque. The majority of its curricular offer is addressed to STEM students, namely: programming and computers; electronics and telecommunications; laboratory analysis and environmental management.

Annex 3: Literature for Innovative STEM Learning

This collection of literature references provides the basis for all future work and publications by the European initiative **Learn STEM**.

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Inspiring Science Education:
http://www.inspiring-science-education.net

Open Discovery Space:
http://www.opendiscoveryspace.eu

Scientix:
http://www.scientix.eu/

Go-Lab:
http://www.go-lab-project.eu/

Go-Erudio:
http://goerudio.pixel-online.org/

Books and materials related to STEM learning and materials:

Design Thinking, toolkit for educators. Online available at:
https://designthinkingforeducators.com/toolkit

Doelgericht werken aan STEM:
https://pincette.vsko.be/meta/properties/dc-identifier/Cur-20170201-12

De STEM-leerkracht:
http://www.kvab.be/sites/default/rest/blobs/121/nw_mw_stemleerkracht.pdf

STEM-kader voor het Vlaams Onderwijs, principes en doelstellingen:
http://ebl.vlaanderen.be/publications/documents/84676

Van Houte, Hilde, Merckx, Bea, De Lange, Jan, & De Bruyker, Melissa. University Applied Sciences Artevelde. *Zin in wetenschappen, wiskunde en techniek.*
http://www.vlor.be/publicatie/zin-wetenschappen-wiskunde-en-techniek

STEM for primary education:
http://www.stembasis.be/stemvoordebasis/

Reflectie instrument STEM:
http://www.stemopschool.be/

STEM-activities Coding:
https://code.org/

Computer science unplugged:
http://csunplugged.org/

Robot activities:
http://www.robotschool.be/

STEM for girls:
http://www.stemsters.be/

Thinkering:
https://tinkering.exploratorium.edu/

TOOLS, onderzoekend leren:
https://www.wur.nl/nl/Onderwijs-Opleidingen/Wetenschapsknooppunt/Expertisegebieden/TOOL-Onderzoekend-Leren.htm

STEM projects:
http://www.stemmom.org/

http://www.stemvoorleerkrachten.be/

Research project University Leuven:
http://www.stematschool.be/nl/

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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