Learn STEM

The Pedagogical Model

for Innovative STEM Learning and Teaching

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Innovative STEM learning in schools

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for Innovative STEM Learning and Teaching

http://www.learn-STEM.org

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Table of Contents

Executive Summary

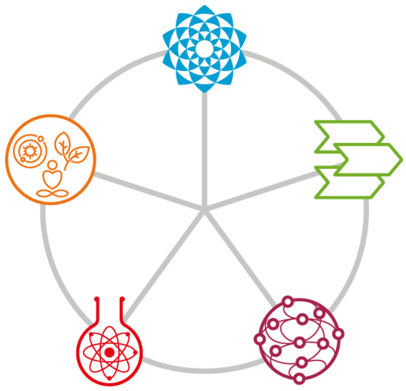
Learn STEM is the **Pedagogical Model for Innovative STEM Learning and Teaching**. It comprises a general framework for improving learning and teaching of Science, Technology, Engineering and Mathematics (STEM) in secondary schools. It has been developed by nine partners from six European countries (The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

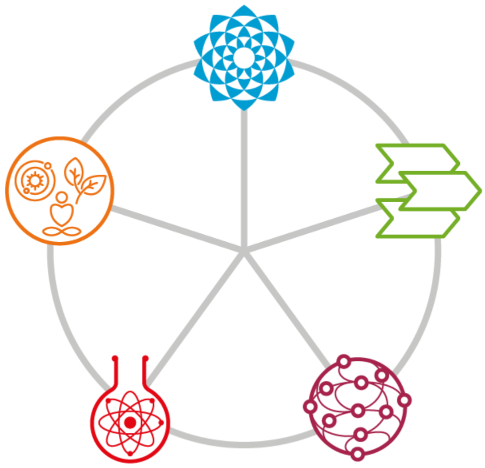


Figure 1: Five characteristics of the **Learn STEM** model

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 insights 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.

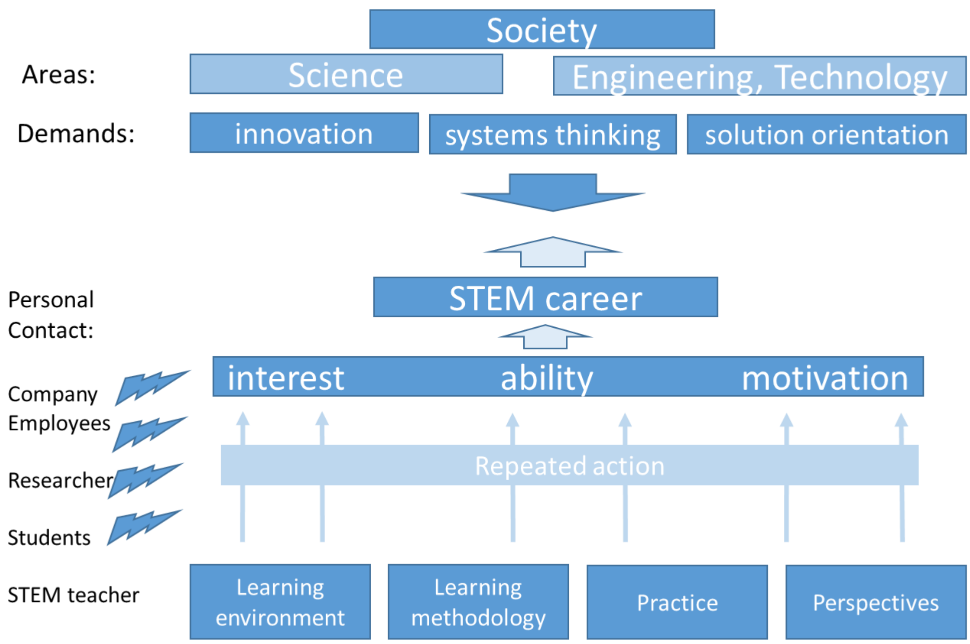


Figure 3: Various factors contributing to the development of stronger STEM interests

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

Technology is becoming more and more part of various areas of everyday life. 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 (Fig. 4) into the classrooms can help to create interrelations between Science, Technology, Engineering and Mathematics (STEM).

Figure 4: Devices involved in the network of Internet of Things.

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

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.

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.

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. 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.

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. 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. 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. 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. Contrary to many expectations, more technology could actually make education more human.

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 interest on 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 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);
- 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 focus on the future. 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 process and a customised career choice. A main subject of interest these days is robotics.

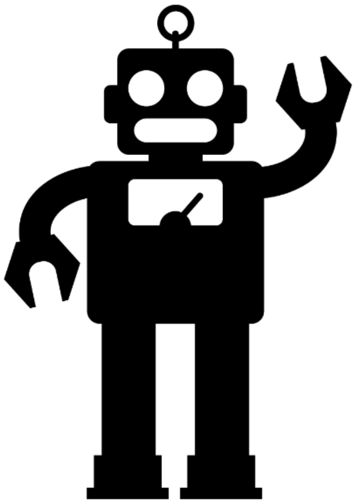


Figure 5: Robotics education prepares learners for the future

How does robotics link to STEM teaching and learning?

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 active 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 on technological impacts. 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 understanding and skills to become discerning decision-makers in the 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. Learners can easily develop a sense of pride, satisfaction and enjoyment from their increasing ability to develop new systems.

5. References for Learn STEM

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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** is 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 also addresses 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 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** is strengthening secondary schools' capacity to develop skills in subjects such as science, technology, engineering and mathematics through innovative and interactive pedagogical methods and approaches. Therefore, **Learn STEM** designs and provides practical instruments and online tools for secondary schools and their teachers and pupils to explore and solve real life questions.

Under the leadership of the coordinator Dr. Christian M. Stracke from the Open University of the Netherlands, **Learn STEM** brings together nine Partners from six European countries. They are collaborating for innovative STEM education and have developed the **Learn STEM** Pedagogical Model, the Inquiry learning package, a teacher training programme and an online course. These instruments are tested, evaluated and continuously improved in close cooperation with hundreds of STEM experts and school teachers. All **Learn STEM** results and achievements are openly and freely available on the **Learn STEM** website online:

http://www.Learn-STEM.org

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