Building high-tech informal learning spaces

The Fablab model and good practices

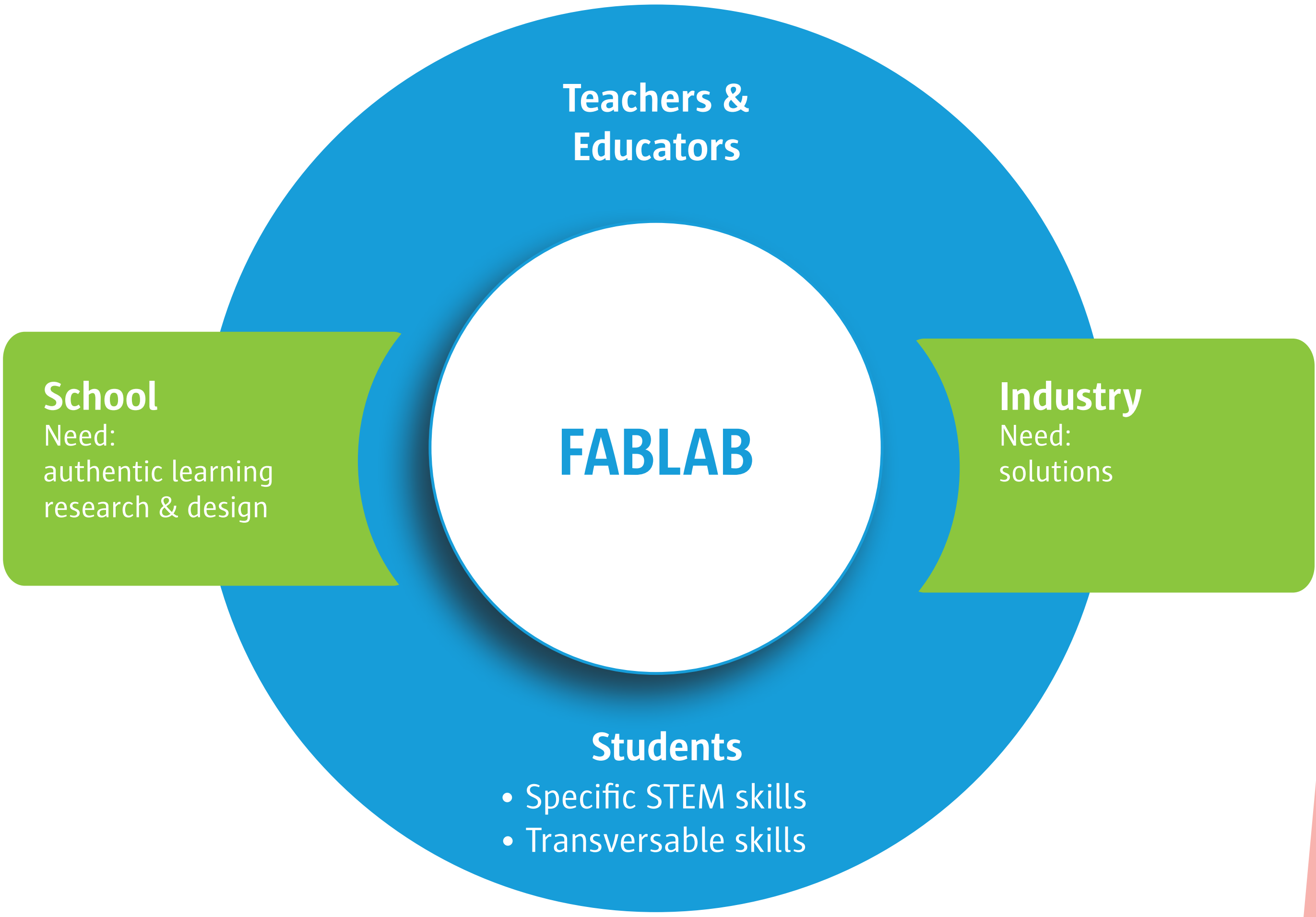
High-tech informal learning environments: an engine for STEM competence development

In chapter 2, we argued that an informal learning environment with technological equipment, is particularly suited to stimulate both STEM specific competences and the development of 21st century skills in students. As a result, teachers need to feel competent to work in such an environment and stimulate competences as problem-solving, creativity, critical thinking, group work, and entrepreneurship. Fortunately, Fablabs and other high-tech informal learning environments such as Makerspaces, Hackerspaces, Robospaces, etcetera, provide ample opportunities for both teachers and students to grow at their own pace.

First of all, the room of a Fablab, which is full of materials and equipment, invites teachers and students to use their imagination, thus contributing to problem-solving and creativity. Also, as the typical restrictions of a traditional classroom disappear, there is more room for exploration and cooperation with others, leading to entrepreneurship and collaborative group work. Hence, informal learning environments appeal to the intrinsic motivation and exploring nature of students. Teachers adopt the role of a coach who incites students to think critically about their actions and who helps them when they are at risk to getting stuck. Second, plenty of materials exist to aid teachers to support the learning process of students. A lot of community knowledge is present in Fablabs and ready to be shared. Also, captivating workshops exist, such as the workshops developed in the Artifex project, to guide teachers through this fascinating and enriching process.

As more and more positive sounds from the field resonate, supported by scientific evidence (e.g. Boaler, 1999; Schwarz & Stolow, 2006; Geier et al., 2008; Vuorikari, Ferrari & Punie, 2019), policy makers are interested in how to optimally shape an informal learning environment, such as a Fablab or Makerspace. Which actors can be involved? And which activities should be encouraged? Within the Artifex project, we propose a theoretical Fablab model, which can serve as a guiding principle when organizing a high-tech informal learning environment.

The FabLab model



The Fablab

The Fablab plays a central role in the model. It represents both the physical place where technological equipment is available and the theoretical concept of an informal open learning environment where both knowledge and tools are shared, and are available for the whole community. In the physical place of a Fablab, you can find high-tech equipment such as laser cutters, robots and 3D printers to build, create, program and develop several artifacts, designs and processes. A Fablab is optimally suited to stimulate exploration and experimenting, as the spaces are less limited than the traditional classrooms. A Fablab is characterized by its accessibility for the larger community, which makes it an excellent place to exchange experiences, knowledge and ideas. Hence, both individual citizens as teachers and their classes are welcome to work and learn in the Fablab, which makes it a place of cross-pollination between ideas from people and groups of different backgrounds. Most Fablabs work according to the principle of open use of the machines (either free or for a small membership fee), and democratic prices for the materials (such as wood, paper, acrylic glass, filament for 3D printers, etc.), in exchange for knowledge, plans and ideas. In principle, visitors prepare their own visit and plans, but the educators and staff of the Fablab are willing to help by explaining the functioning of the machines and by organizing theoretical and practical workshops.

The Fablab is literally and figuratively the center of the model. In this representation, we use the word 'Fablab' as the indicator for the room and the concept of an informal learning environment with technological equipment. Of course, this can be interchangeably used with other forms of high-tech informal learning environments, such as Makerspaces, Hackerspaces, Robospaces, etc.

In the Fablab, multiple actors can come together and be of added value to each other. Two major stakeholders are the schools and the industry. Within the Fablabs, teachers, educators and students physically come together, in order to improve students' specific STEM skills and the more generic 21st century skills (or transversable skills).

School

A first important stakeholder within the Fablab organization are the schools. As traditional classrooms are not optimally adapted for stimulating 21st century skills, schools need informal learning environments beyond the physical boundaries of the classroom walls. Educational contexts which are both fitted to stimulate the development of specific STEM skills and more generic skills, are the perfect breeding ground to prepare students for the future. Research shows that authentic real-world problems create a challenging, motivating and enjoyable way to learn (Colliver, 2000). Hence, schools need realistic contexts that resemble challenges encountered by STEM professionals in the workplace (De Loof, 2019). In these contexts, learning is often problem-centered, which means that a problematic situation serves as the organizing center and context for meaningful learning. In this way, the relevance of STEM content becomes more clear for the students (Thibaut et al., 2018). The challenges that are offered to the students in a Fablab are meaningful, often open-ended and allow multiple solution paths. Also, they are very suitable for collaborative group work. Indeed, a study of Merrill and Gilbert (2008) demonstrated that problem-centered learning is most effective when combined with appropriate peer interaction.

Authentic problem-based learning follows typically a research or design cycle. Both start with a 'problem': either a research question or an identified need. The research cycle typically follows these steps: 1) formulate research question, 2) plan, 3) collect data, 4) interpret data, 5) evaluate results, 6) present research findings. The design cycle follows a more or less analogous path, consisting of the following steps: 1) identify need, 2) generate ideas, 3) plan, 4) develop design, 5) evaluate design. Research and design cycles are good examples of activities that can be done in a Fablab to stimulate both specific and generic STEM skills in a realistic context. More information about research and design cycles can be found in Chapter 2.

To summarize, **schools need authentic contexts for STEM learning,** which can be found in high-tech informal learning environments such as Fablabs.

Industry

A second important stakeholder is the industry. The industry can benefit from the presence of Fablabs in society in two ways. First, there is the direct advantage of having contact with teachers, educators, students and individual users within the community.

The industry often needs innovative solutions for a range of problems. Within the context of the Fablab, they could meet other actors who can help to find these solutions. For instance, small companies can meet other people in the Fablab and make valuable connections. Projects can be launched in which other companies or educational organizations are involved. Second, there is the indirect profit from a future workforce that is skilled and motivated. Currently, students gradually leave STEM throughout their educational trajectory, which leads to both a qualitative and a quantitative shortage on the labor market (Keith, 2018).

The drop-out at various points along students' educational careers is described in the literature in terms of a 'leaky pipeline' (Watt et al., 2012). Because the activities in high-tech informal learning environments are committed to be a challenging, motivating and enjoyable way to learn, while increasing STEM knowledge and application, they have the potential to prevent students from losing interest in STEM and dropping out of a STEM educational trajectory. The industry benefits largely from motivated and skilled STEM students, as they are the future for the whole field. Also contact with teachers is valuable, as the industry benefits from the teachers who are up-to-date with industry developments. Teachers who are informed about actual business requirements, can adapt their workshops or courses and in this way optimally prepare students for a possible STEM future.

To summarize, the industry needs solutions for both current and future challenges that demand valuable professional contacts and a skilled workforce.

Teachers and educators

Teachers and educators play a special role in the high-tech informal learning environment. In contrast to traditional teaching, which is mainly teacher-centered (i.e. the teacher gives information at the front of the classroom to the students who are listening to this information), the learning activities in a Fablab are predominantly student-centered. A student-centered learning environment provides students the opportunity to take a more active role in their own learning, rather than being a passive receiver of information. This student-centered approach in STEM learning supports students' engagement (Struyf, De Loof, Boeve-de Pauw, & Van Petegem, 2019). When a teacher adopts a student-centered approach, this means that the teacher takes up the role of a coach, a motivator and a mentor. More specifically, he or she sets the outlines and provides a framework in which students can experiment and investigate. For instance, the teacher can challenge the students with an assignment and help them to go through the research or design cycle. Within those outlines and framework, students can bring up ideas and ask themselves questions which they find worth investigating. Student-centeredness is reflected by respectful interactions between student and teachers, in which the teacher acknowledges and supports the initiatives coming from the students (Struyf et al., 2019).

Besides adopting the role of a coach, teachers are also part of the learning process themselves. Preferably, they learn along with the students. As not every teacher is very acquainted with informal learning environments in general, and more specific, with high-tech informal learning environments as Fablabs, they can go through a learning trajectory themselves. This requires a willingness to learn at the one hand, and the ability to 'let go' of the all-knowing role on the other hand. At the same time, it is important that the teacher feels competent, when visiting the Fablab with the students, especially when they go through a learning trajectory themselves. For instance, teachers can help to stimulate 21st century skills within students, without being familiar with all the specific knowledge about the machines in the Fablab. When teachers and educators feel competent and comfortable in their role as a coach, they can optimally guide the learning experiences of students. Within Artifex, teachers are encouraged to develop their own competences with regard to stimulating students 21st century skills in a high-tech learning environment. They can choose from a variety of workshops that are adjusted to their level. Teachers can gain insight in their strengths and weaknesses (which determine their level) through the self-assessment tool

To summarize, teachers and educators are coaches in the learning processes of students in Fablabs and can go through a learning process themselves.

Students

As described above, students benefit most from a student-centered approach with a focus on problem-based active learning. They go through research and design cycles, thus improving their STEM specific knowledge and developing their 21st century skills. With STEM specific knowledge, we allude to the content knowledge and applications of science, technology, engineering and mathematics. For instance, thermal energy and phase transitions (science), building solar collectors with appropriate materials (technology), programming control loops with Arduino (engineering) and trigonometry, elementary mathematical functions, and sequences (mathematics), are all STEM content knowledge and applications. In the literature, the exact meaning of STEM and the accompanying learning concepts is subject of debate, but this terminology becomes less relevant when STEM is approached as an integrated concept. The given examples of content knowledge and applications can for instance be integrated in a learning activity of building an energy-neutral house. Previous research has shown that an integrated approach on STEM leads to improved content knowledge for some subdomains (De Loof, 2019). Integrated STEM assignments are learning activities that can benefit highly from the presence of a high-tech informal learning environment, as these environments can provide ample materials and equipment and are optimally suited to stimulate generic skills that are essential for completing the assignment successfully (i.e. problem solving, creativity, critical thinking, group work and entrepreneurship).
Many societal challenges that we are facing, such as global warming, shrinking resources, an aging society, traffic problems, etcetera, (partially) require STEM solutions (Wang, Moore, Roehrig, & Park, 2011). Students that are motivated and interested in STEM, while at the same time being competent (both regarding specific STEM skills and transversable skills), are essential for the future of our society.

To summarize, students can develop specific STEM skills and transverable skills in Fablabs.

Good practices

Across Europe, multiple initiatives have arisen to establish open community spaces in which high-technological material is available. These spaces differ in their functioning, their name, and the specific nature of the activities, but start from the same principles: materials and equipment is available for the broader community, learning is encouraged, and fruitful partnerships can emerge. An overview of the current Fablabs all over the world can be found on this map: https://www.fablabs.io/labs/map.
We provide some good practices that can serve as an inspiration for policy makers and educators who want to start their own initiative or improve their current practice.

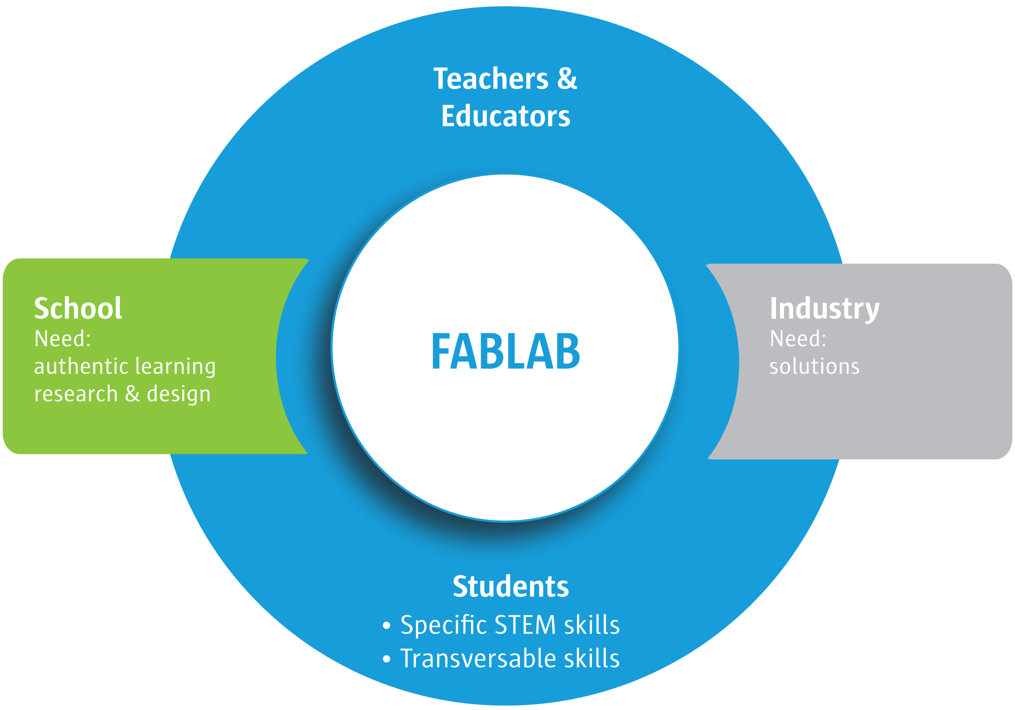
Fablab+ - Belgium

Fablab+ was founded in the city of Antwerp, as a response to the increasing demand of schools for high-tech STEM tools. A few secondary schools of the Municipal Education of Antwerp wanted to invest in these tools, and as it was not possible to invest in a broad arsenal of high-tech STEM infrastructure by each school separately, they had the idea to invest in a common Fablab. Fablab+ has an outstanding array of equipment: they have prototyping tools (3D-printers, laser cutters), IT and machining techniques (CNC-mills), but they also have robotics.

As the Fablab is getting more and more filled with equipment, Fablab+ plans to move a lot of the multimedia equipment (Virtual Reality and Augmented Reality) to a new multimedia lab, which will give them more room for building activities.

Another strength of Fablab+ is their pedagogical support. The staff of the Fablab (consisting of three lab managers who all have former expertise in education) does not fabricate the designs of its visitors, but they enable the visitors to make it themselves, from a digital design to a tangible object. They teach problem solving and research based learning (i.e. the research cycle) to teachers and teacher trainers and support them when they come to the Fablab with their students.

Fablab+ is open to both schools and to the general public. On a practical level, they have days that are exclusively reserved for schools, teachers, professionals and intermediate organizations with a link to STEM. On other days, the Fablab is open without reservation for everyone else. Then, there is a 'first come, first serve'-system.
When considering the theoretical Fablab model, you might say that Fablab+ has a very strong focus on their educational support, while providing a broad array of high-tech equipment. The educational support consists of a highly skilled staff with educational background, who are specialized in supporting teachers in problem-based student-centered STEM education. Also, with fixed days that are reserved for STEM education, they provide room and space for schools and their students to experiment and create in a sheltered environment. One part of the model where Fablab+ would like to improve, is the industry part. Currently, they have collaborations with partners of the industry for specific grants and open calls, but in the future, they would like to include informal contacts with the industry. The Fablab could work as a liaison between industry and teachers and educators, and lower the threshold between these partners.

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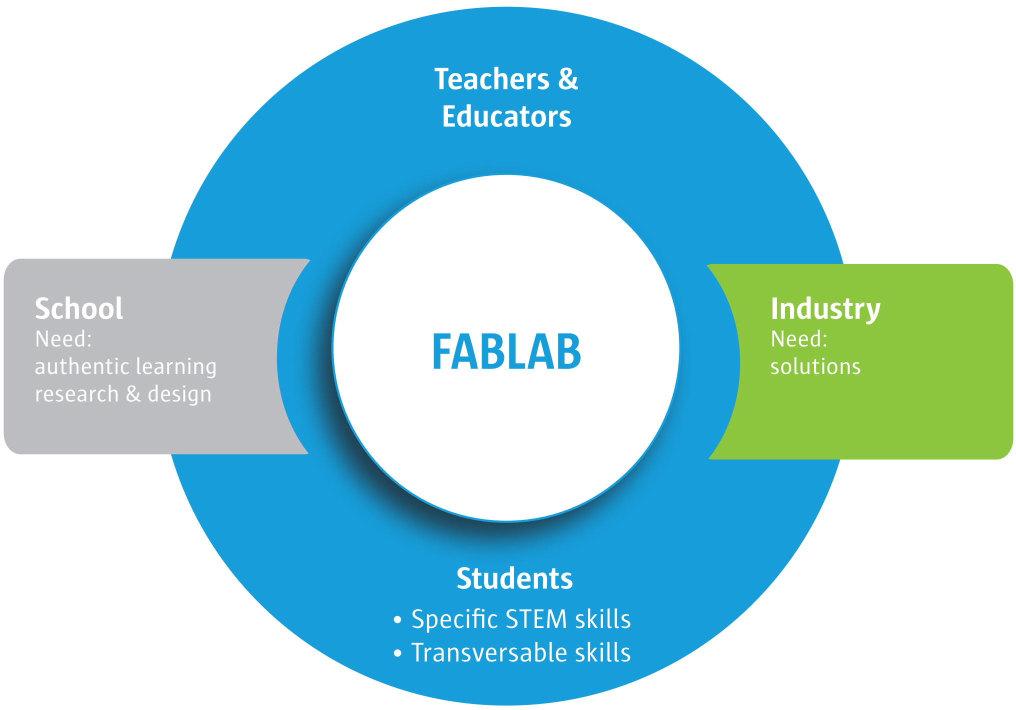
Karstad Makers - Sweden

Karlstad Makers is a makerspace with a diverse machine park and tools. Examples of machinery are sanders, 3D-printers, drills, saws, a CNC-cutter, a Virtual Reality-set, etcetera. Karlstad Makers is part of the Karlstad Innovation Park, which is a one of the Swedish incubators and science parks. The goal of the innovation park is to contribute to the development of innovation and growth within Sweden. The innovation park serves as a meeting point for people, knowledge and creativity, and supports people and companies with growth ambitions. Both people who want to start a new company and people who already own a company but want to improve their business, can benefit from the expertise and experience. Karlstad Makers is thus surrounded by a lot of small innovative companies, which makes it the perfect spot for creative encounters and establishing a network.

Karlstad Makers also collaborates with universities and schools, with projects related to science and technology which aim to clarify and illustrate complicated contexts. Karlstad Makers works with a paying membership. Members have limitless access to the makerspace and it tools and can follow free workshops and introduction courses about the use of the equipment.

An example is a training about 3D-technology. Besides the formal workshops organized by the makerspace, members also learn from each other.

When considering the theoretical Fablab model, the Makerspace is in the center, as it is a high-tech open informal learning environment. A great strength of Karlstad Makers is its connection with the industry. Due to its physical proximity to innovative start-ups and companies, cross-fertilization between people, ideas and companies can take place. Learners and makers are directly confronted with real-life STEM contexts and can in turn share their ideas and insights. While Fablab Makers welcomes students and organizes workshops, they have no fixed school section within their functioning. Currently, they receive a lot of questions of schools and universities, but they lack sufficient room to be able to accommodate to these needs.

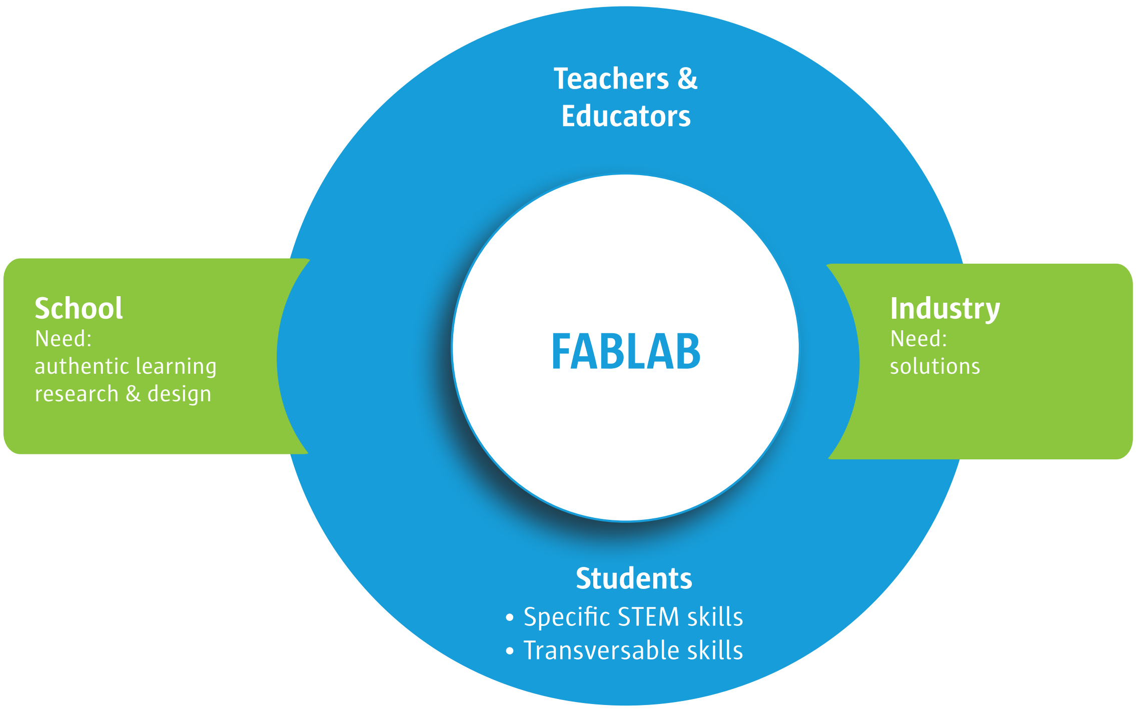


Fablab Brno – Czech Republic

Fablab Brno is the first Fablab in the Czech Republic and was founded in 2017 by the South Moravian Innovation Centre. The Fablab is situated in the building of the JIC. The JIC is an organization which supports entrepreneurs. They create a meeting space where entrepreneurs can share experiences and know-how and where they can initiate professional partnerships. The JIC also helps to launch your enterprise, or provides new perspectives when you are struggling with your current business. Besides consulting, the JIC also organizes educational events for future and current entrepreneurs. In the JIC-building, you can rent an office, a conference room, a lecture hall, or a lab, and make use of the Fablab. As the Fablab is run by the JIC, there is a strong focus on empowering companies with the Fablab. Companies can benefit from equipment that would not be accessible otherwise and they can submit their problems to the core team or the Fablab community.

The Fablab has a CNC-milling machine, a gearbox, a bending machine for plastic, 3D-printers, a laser- and vinyl cutter, and an embroidery machine amongst its machinery. The Fablab is open 24/7 for everyone above 15 years. Their members are affiliated with universities, but also with the industry. Fablab Brno organizes around twenty events a month, in which they aim at the participation of the general public. These events are educational workshops, hackathons, Fablab tours, etc.

The Fablab also reaches out to primary and secondary schools, by bringing the Fablab to them. They have a special Fablab truck which is filled with technology. The full size trailer is called 'The FabLab Experience' and contains, amongst other tools, a 3D-printer, an electron microscope, a cooperative robot, and a cutting plotter and termolis. The Fablab Experience reaches more than 10 000 youngsters per year and is completely free. This way, they also reach schools that have difficulties to organize excursions. In the truck, experienced instructors help to design creative projects and train schools in digital production technology. Students can not only learn about the latest information concerning modern production and prototyping, but also test the machines themselves. While all the elements of the Fablab model are prominently present, the relations between the school and the industry could be reinforced in the future. Now, industry and schools visit the Fablab rather separately.

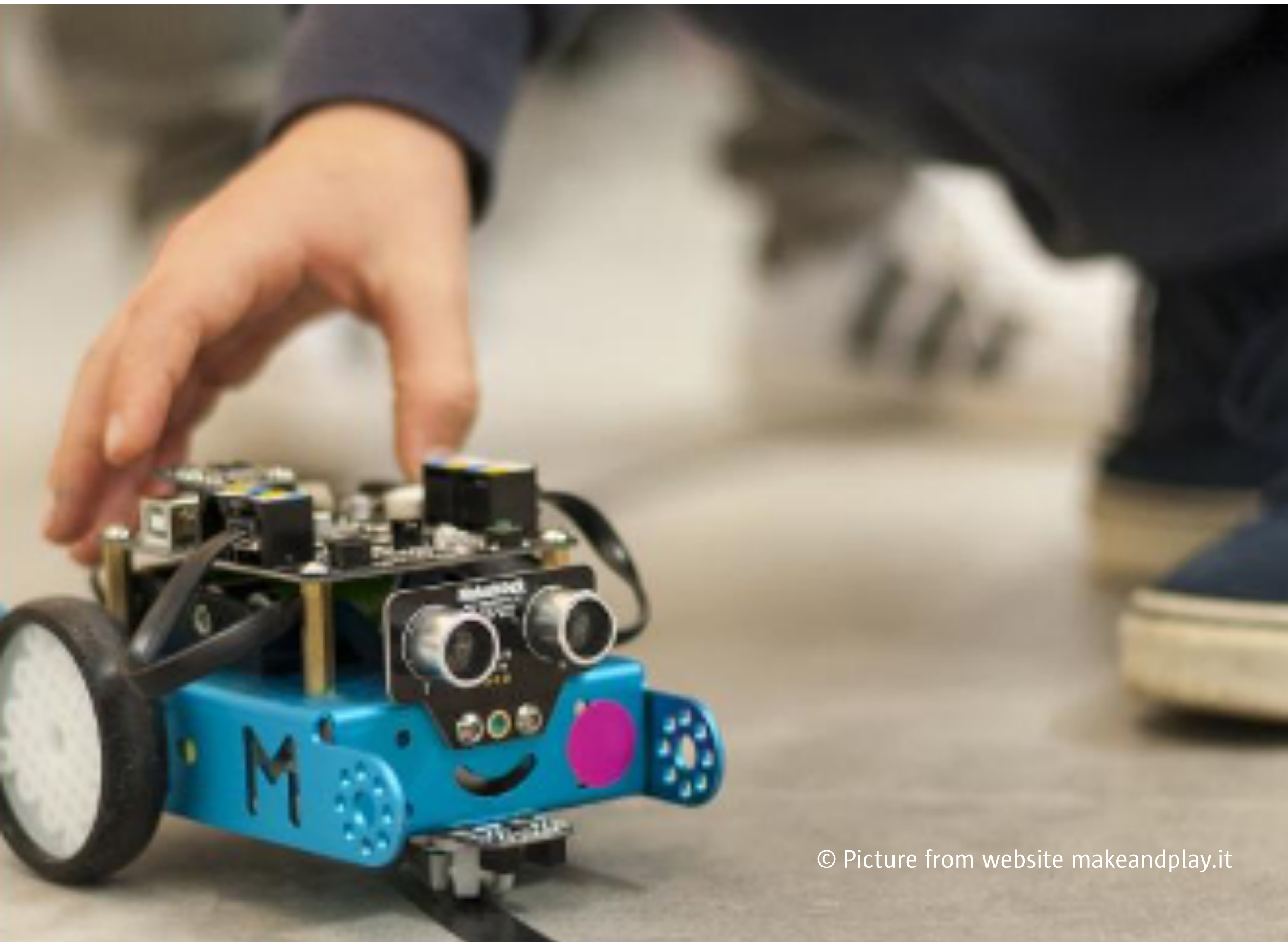


Fablab Casterfranco Veneto

Fablab Casterfranco Veneto is located in the artisans area of the well-preserved medieval town of Castelfranco Veneto. The Fablab started as the fusion of a few non-profit associations, one related to Linux (the open source operating system), one to Arduino (the open source electronic board), and one related to family policies in the city of Casterfranco Veneto. Their goal was to spread knowledge about programming and electronic topics and they did that by organizing public events and lectures at schools. Currently, the Fablab is the heart of this knowledge dissemination and multiple projects are carried out.

For instance, the 'Make and Play' format, which is designed to bring children closer to electronics, robotics, programming, and digital production. The goals is to raise awareness for the use of technology and the application of science in a playful and fun way.

Fablab Castelfranco Veneto has large spaces and lots of equipment, such as work benches, electronic boards, 3D-scanners, 3D-printers (for wax and polylactic acid), a cutting plotter, a milling machine, and a laser cutter. The Fablab is an open space. First, it is open in a physical way: the room is filled with digital fabrication tools, prototype materials, and tables and



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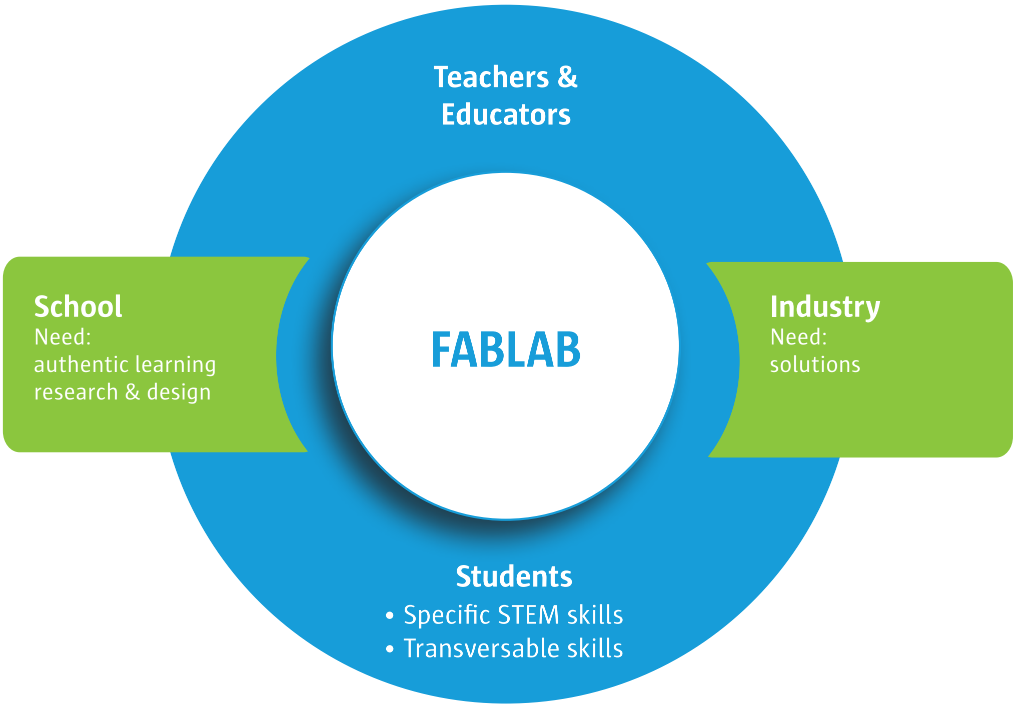


chairs, but all this can be easily removed or reconfigured depending the specific needs. Second, it is also open in a conceptual way: Fablab Castelfranco Veneto collaborates on a daily basis with companies and professionals and schools and students. For companies, they make 2D- and 3D-files for the production of object and artefacts. Also, they follow the most recent development of software and hardware. This way, the Fablab supports companies and design studios for the realization of their products. Also, the Fablab organizes workshops and courses.

For schools and students, Fablab Castelfranco Veneto organizes 'Fablab explore tours' for children, engages children in the Make and Play-format, and organizes internships for universities. Students who are visiting the Fablab, are asked to work on 'industrial level projects' with other tools than they usually utilize in schools, to provide insight in how industrial projects are regularly done. For individual makers, the courses, machines and software of the Fablab are also available.
Thanks to their activities with multiple actors, Fablab Castelfranco Veneto knows the demands of the companies and their way to dissolve them. They also know how the students are taught new learning contents. For the schools, their mission is to make clear what STEM is about, and how it is possible to integrate these disciplines in the everyday teaching.

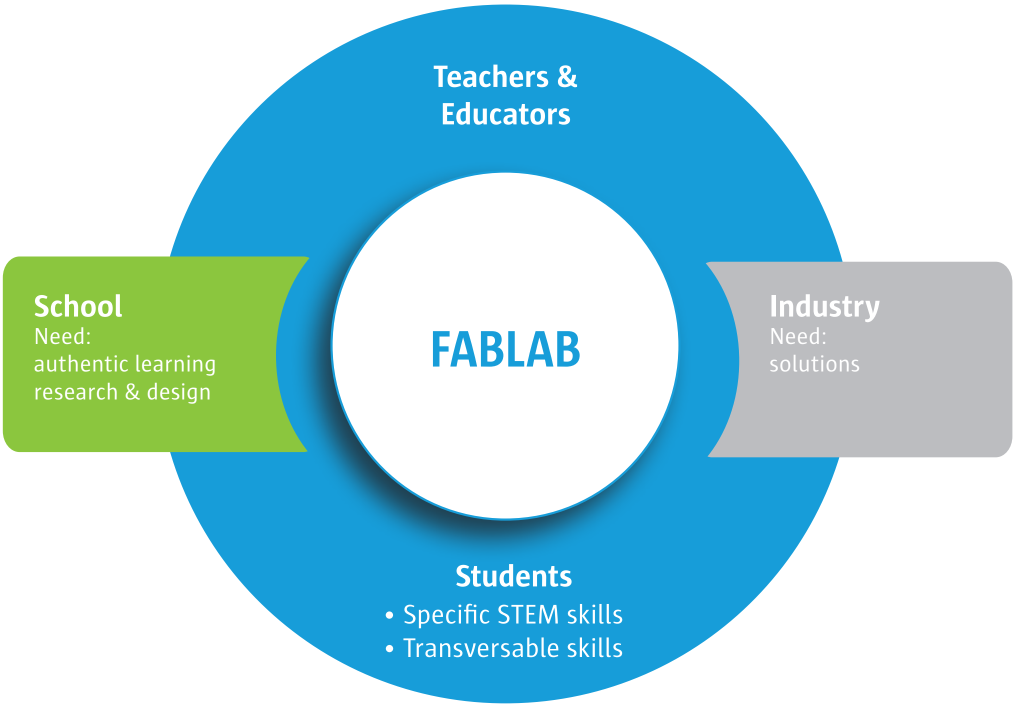
With regard to the theoretical Fablab model, all actors are present. Nevertheless, Fablab Castelfranco Veneto, would like to strengthen the relationships between schools and industry. In the past, they had two very successful collaborations, and they are open to welcome more. Therefore, they would like to start working on a few meetings for teachers and industries, to let them discuss topics on which they can collaborate.

Fablab@SCHOOLdk – Denmark

Fablab@SCHOOLdk is a partnership of four Danish municipalities: Vejle, Silkeborg, Kolding and Middelfart. Every municipality has a central Fablab in which teachers can educate themselves in the field of digital fabrication and design. The four municipalities act as a network for project leaders, Fablab educators, teachers, pedagogues, principals, librarians or other professionals who support the development of STEM-literacy (e.g. understanding of technology and practical skills), and 21st century skills in schools and communities.

The staff at the central Fablab facilitates the learning of the professionals, invites them to investigate different technologies and reflect on their learning potential with colleagues. When the professionals have sufficient technological skills they are supported to develop a local Fablab or Makerspace in their schools. Hence, the goal is that teachers implement this knowledge and skills into their own teaching practice. What's more, Fablab@SCHOOLdk encourages teachers to implement STEM activities into all subjects (language, handcraft, history, social studies, music, science, biology, sport, etc.).

Fablab@SCHOOLdk also organizes activities for students, but their ultimate goal is to empower the teachers to do such activities themselves (i.e. learning to learn). Fablab@SCHOOLdk supports both students and teachers in learning how they can explore technologies, how they can adopt strategies for troubleshooting, and where they can find support in online or physical networks. The students and teachers are approached in the same way by the Fablab, and they are encouraged to learn together.



Once a week, the central FabLab is open for everybody. On these days, you can find a mixture of professionals and volunteers.

As Fablab@SCHOOLdk mainly focusses on 'teaching the teachers', the educational stakeholders are the most important element in the theoretical model. Looking towards the future, Fablab@SCHOOLdk hopes to educate children about digital technologies and how they impact the way that they are living, learning and communicating. They want to use the same strategy as today: to educate teachers, parents, principals, etcetera, about the dependency on technology, and to raise awareness on how technologies works. That way, they eventually want to empower children and youngsters to be conscious and critical consumers and producers of digital artifacts.

References

Boaler, J. (1999). Mathematics for the moment, or the millennium? Education Week, 17(29), 30–34.

Colliver, J. A. (2000). Effectiveness of problem-based learning curricula: research and theory. Academic Medicine, 75(3), 259-266.

De Loof, H. (2019). Educating engaged and competent students for STEM: effects of integrated STEM education. University of Antwerp.

Geier, R., P. C. Blumenfeld, R. W. Marx, J. S. Krajcik, E. Soloway, & J. Clay-Chambers. (2008). Standardized test outcomes for students engaged in inquiry-based curricula in the context of urban reform. Journal of Research in Science Teaching 45(8), 922–39

Keith, K. (2018). Case Study: Exploring the Implementation of an Integrated STEM Curriculum Program in Elementary First Grade Classes (Doctoral dissertation). Concordia University, Portland.

Merrill, M. D., & Gilbert, C. G. (2008). Effective peer interaction in a problem- centered instructional strategy. Distance Education, 29(2), 199-207.

Schwarz, E., & Stolow, D. (2006). Twenty-first century learning in afterschool. New Directions for Youth Development, 110, 81–99.

Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: Integrated STEM education as promising practice? International Journal of Science Education, DOI: 10.1080/09500693.2019.1607983

Thibaut, L., Ceuppens, S., De Loof, H., De Meester, J., Goovaerts, L., Struyf, A., ... & Hellinckx, L. (2018). Integrated STEM Education: A Systematic Review of Instructional Practices in Secondary Education. European Journal of STEM Education, 3(1), 1-12.

Vuorikari, R., Ferrari, A., Punie, Y., Makerspaces for Education and Training – Exploring future implications for Europe, EUR 29819 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-09032-8, doi:10.2760/946996, JRC117481.

Wang, H. H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM integration: Teacher perceptions and practice. Journal of Pre-College Engineering Education Research, 1(2), 1-13.

Watt, H. M., Shapka, J. D., Morris, Z. A., Durik, A. M., Keating, D. P., & Eccles, J. S. (2012). Gendered motivational processes affecting high school mathematics participation, educational aspirations, and career plans: A comparison of samples from Australia, Canada, and the United States. Developmental Psychology, 48(6), 1594-1611.