Co-funded by the Erasmus+ Programme of the European Union

2017-1-LT01-KA203-035231

HEI MAKERS

O1 Guidelines for HEIs on employing a Makerspace

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Vilnius, 2018

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Terminology

The idea of a university innovation space is quite recent, with the first one dating back to Massachusetts Institute of Technology (MIT) makerspace around 2001 (Barrett et al., 2015). While makerspaces are appearing in many universities and engineering schools across the countries, there is still very little empirical assessment of the spaces.

There are a number of definitions of open or collaborative workshops. For example, Verbund Offener Werkstätten (2014) describes them as open collaborative spaces with equipment and tools available to all technically and artistically active individuals (hackers, makers, crafters, tinkerers, and artists) and their groups allowing them to work on their software, hardware, or art projects.

According to Craig Forest *et al.* (2016), makerspaces are places where "*users work side by side on different projects within an open culture of collaboration. Makerspaces are generally equipped with traditional manufacturing equipment* […] *and emerging rapid prototyping tools.* […] *They empower their users to develop, build and test physical prototypes*".

The definition of open workshops given by Kostakis et al. (2014) describes them as physical places working on the basis of the community created around them, where individuals are immersed in the culture and ethics of each place and are able to engage with meaningful and creative projects. Thus, the authors stress the community basis of every workshop and the specific environment and ethics present in it (Iscenco 2015).

These places empower the users to innovate without constraining their imagination or creativity (Barrett 2015).

There can be many types of university makerspaces according to management type, budget structure, theme.

- Management type: student run, faculty run, specific staff run.
- Scope of supervision: always supervised, partly supervised.
- Budget structure: funded by university, funded by university and business, funded by community.
- Theme: engineering and mechanics, engineering + multimedia, engineering + multimedia + entrepreneurship.
- Location: on campus / off campus.
- Membership: university access only, open to the community.

As a makerspace can be anything from a repurposed book cart filled with arts and crafts supplies to a table in a corner set out with LEGOs to a full blown fab lab with 3D printers, laser cutters, and hand tools, there is no single definition for it. No two makerspaces are exactly alike, nor should they be. Makerspaces are as unique as the cultures they represent. In our project the definitions of a makerspace, maker culture, maker, hackerspace and FabLab can be interpreted as follows:

A makerspace is a collaborative work space inside a school, library or separate public/private facility for making, learning, exploring and sharing that uses high tech to no tech tools. These spaces are open to kids, adults, and entrepreneurs and have a variety of maker equipment including 3D printers, laser cutters, CNC machines, soldering irons and even sewing machines. A makerspace however doesn't need to include all of these machines or even any of them to be considered a makerspace. If you have cardboard, Legos and art supplies you're in business. It's more of the maker mindset of creating something out of nothing and exploring your own interests that's at the core of a makerspace. These spaces are also helping to prepare those who need the critical 21st century skills in the fields of science, technology, engineering, arts and math (STEAM). They provide hands on learning, help with critical thinking skills and even boost self-confidence. Some of the skills that are learned in a makerspace pertain to electronics, 3D printing, 3D modelling, coding, robotics and even wood-working, Makerspaces are also fostering entrepreneurship and are being utilized as incubators and accelerators for business start-ups (https://www.makerspaces.com/what-is-a-makerspace/).

The **maker culture** is a contemporary culture or subculture representing a technology-based extension of DIY culture that intersects with hacker culture (which is less concerned with physical objects as it focuses on software) and revels in the creation of new devices as well as tinkering with existing ones. The maker culture in general supports open-source hardware. Typical interests enjoyed by the maker culture include engineering-oriented pursuits such as electronics, robotics, 3D printing, and the use of Computer Numeric Control tools, as well as more traditional activities such as metalworking, woodworking, and, mainly, its predecessor, the traditional arts and crafts. The subculture stresses a cut-and-paste approach to standardized hobbyist technologies, and encourages cookbook re-use of designs published on websites and maker-oriented publications. There is a strong focus on using and learning practical skills and applying them to reference designs (https://en.wikipedia.org/wiki/Maker_culture).

Maker [**mey**-ker] noun 1. a person or thing that makes. 2. a manufacturer (used in combination): *drugmaker; garmentmaker*. (http://www.dictionary.com/browse/maker).

A **hackerspace** is a community-operated, often not for profit, work space where people with common interests, often in computers, machining, technology, science, digital art or electronic art, can meet, socialize and collaborate. Hackerspaces are comparable to other community-operated spaces with similar aims and mechanisms such as Fab Lab, men's sheds, and commercial for-profit companies such as TechShop (https://en.wikipedia.org/wiki/Hackerspace).

FabLab is the educational outreach component of MIT's Center for Bits and Atoms (CBA), an extension of its research into digital fabrication and computation. A Fab Lab is a technical prototyping platform for innovation and invention, providing stimulus for local entrepreneurship. A Fab Lab is also a platform for learning and innovation: a place to play, to create, to learn, to mentor, to invent. To be a Fab Lab means connecting to a global community of learners, educators, technologists, researchers, makers and innovators – a knowledge sharing network that spans 30 countries and 24 time zones. Because all Fab Labs share common tools and processes, the program is building a global network, a distributed laboratory for research and invention (http://www.fabfoundation.org/index.php/what-is-a-fab-lab/index.html).

Current situation worldwide

Due to the vast number of types of the makerspaces and lack of it's promotion and online presence, it is challenging to pick out all the cases in one somewhat comparable list. Nevertheless, since majority of such spaces are licenced as FabLabs or at least categorize itself that way – we referenced the user generated list having 1260 FabLabs around the world and picked out all the European ones (see Figure 1). This left us with 499 makerspaces in hand as of year 2018. And finally – 80, when we filtered out all the private ones, as well as the ones that are least promoted or online present.

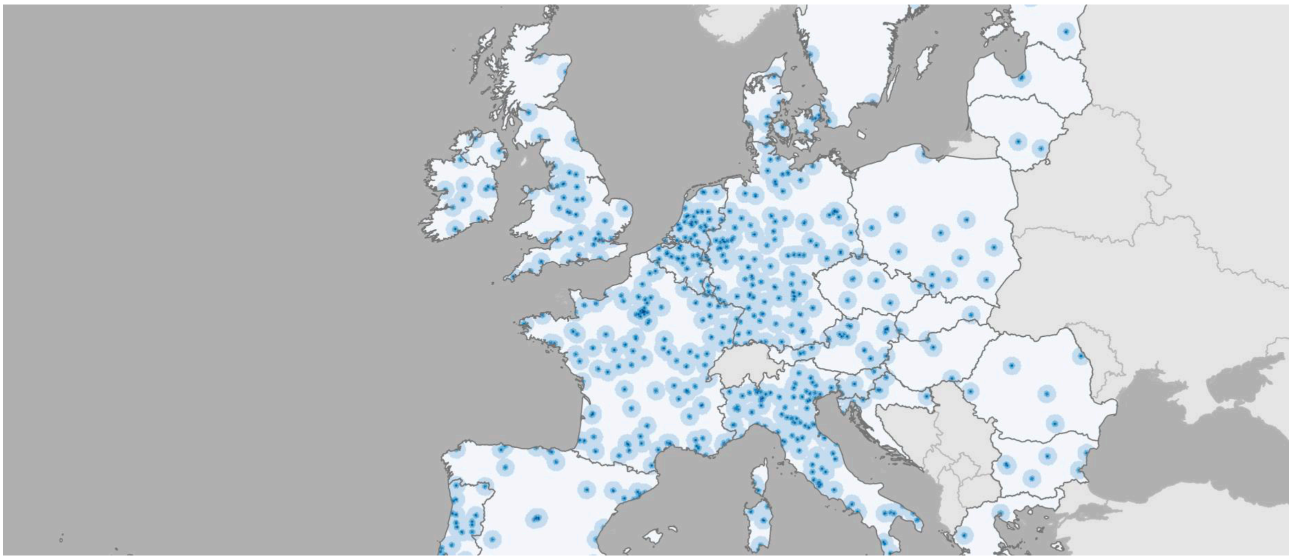

Figure 1. Makerspaces in Europe (Source: https://ec.europa.eu/jrc/en/publication/overview-maker-movement-european-union)

Out of 80 university makerspaces: 7 were a result of university consortia, 4 as a joint venture by a university and private business, and the rest of it – a fully university owned makerspace.

The size varied from 100 to 2600 sq. m. The biggest being Drahi X-Novation Centre (XF4B) at Ecole Polytechnique in France (2600 sq. m.) and DTU Skylab at Technical University of Denmark (1550 sq. m.).

Table 1. Makerspace equipment tendencies

Permanently seen	Very often encountered	Complementary, regularly	Original, rare
3D printer	Electronics	Audio	Robotics
CNC	Printing	Video	Virtual reality
Laser cutter	Graphics / Design	Photo	Augmented reality
	Metal	Painting	Artificial Intelligence
	Wood	Arduino	Startup incubator

		Textile	

Talking about the theme of university makerspaces, majority were clearly engineering oriented (mostly rapid prototyping). All 80 units had 3D printers, which appears to be absolute mandatory to have in order to call yourself a makerspace. Ironically, for some places that call themselves a makerspace, it‘s all they have – a 20 sq. m. room with a few 3D printers available. This adds to the previously mentioned limitation of makerspace research.

Other kinds of equipment were found in the abovementioned research in the following proportions: metal – 71, wood – 53, electronics – 56, computing – 55, painting/dying – 7, audio – 8, textile – 18, photo/video – 16, 3D modelling and graphic design – 42, startup incubator – 18.

In addition to using modern tools, another way of making is through upcycling, the intentional transformation of hard-to-recycle materials into new products, thus saving them from the landfill. Most of the makerspaces organise workshops and projects in upcycling. This type of real-world project not only teaches making skills but also helps to integrate making into particular subject area, e. g. material science, industrial design, environmental education. As an added bonus, upcycling projects ignites students' entrepreneurial spirit.

Only 55 out of 80 university makerspaces have their own Facebook business page.

Country profile (Lithuania, Latvia, Romania)

Lithuania

Lithuania's startup ecosystem is in a relatively early stage, however the success stories are well worth praising. Among its first tech startups was GetJar, an independent mobile app store founded in 2004 and sold to Sungy Mobile in 2014. Other successful and widely recognised startups include Pixelmator, a popular image editor for Mac OS and iOS, as well as Trafi, which was awarded as the best Travel Planner for public transport during the 2016 Olympic Games. Another successful example is Vinted, a peer-to-peer clothes marketplace that has raised almost $60 million to date and expanded across Europe and the US. Oxipit - Lithuanian AI startup focusing on medical problems – won 1st Place in Intel & MobileODT Cervical Cancer Screening Competition, The Nature Conservancy Fisheries Monitoring Competition and has been selected as one of the top projects for the 2018 Society for Imaging Informatics in Medicine (SIIM) Innovation Challenge.

The makerspace culture is relatively young in Lithuania. All the major makerspaces are listed in the table below.

Table 2. Makerspace overview in Lithuania

IDENTITY		**ENGINEERING FIELDS**						**ARTISTRY/ MEDIA FIELDS**						
Name of the Makerspace	Status	3D	Metal	Wood	Electronics	IT	Product design / Modelling	Painting	Audio	Photo/ Video	Textile	Graphic Design	2D printing, stickers, badges, etc.	VR/AR/MR / Game Dev
VGTU "LinkMenų fabrikas"	University	X	X	X	X	X	X	X	X	X	–	X	X	X
M-Lab, the FabLab of Vilnius	Private	X	–	X	X	–	X	–	–	–	–	–	X	–
FabLab Kaunas	University	X	X	–	X	–	–	–	–	–	–	–	–	–
Technariumas	Private	X	X	X	X	–	–	–	–	–	–	–	–	–
Padirbtuvės	Private	X	–	X	X	–	–	–	–	–	–	–	–	–

PATS SAU Makerspace	Library	X	–	–	X	X	–	–	–	–	–	–	X	–
Kaunas Makerspace	Private	X	–	X	X	X	–	–	–	–	X	–	–	–

Latvia

Start-up environment in Latvia is growing rapidly and purposefully. And according to the World Economic Forum data Latvia is one of the Europe's entrepreneurial hotspots (https://goo.gl/yafVKP). Various events devoted to the development of the start-up culture take place in Latvia - Digital Freedom Festival, TechChill, #StartUpTheSeason, etc.

Table 3. Makerspace overview in Latvia

IDENTITY		ENGINEERING FIELDS						ARTISTRY/ MEDIA FIELDS						
Name of the Makerspace	Status	3D	Metal	Wood	Electronics	IT	Product design / Modelling	Painting	Audio	Photo/ Video	Textile	Graphic Design	2D printing, stickers, badges, etc.	VR/AR/MR / Game Dev
Latvenergo radošā laboratorija	University	X	–	X	X	X	X	–	–	–	–	–	–	–
RTU Design lab	University	X	–	X	X	X	X	–	–	–	–	X	X	–
IEVF radošā laboratorija	University	X	–	X		X	–	–	–	–	–	–	–	–
Robotikas klubs	University	X	–	–	X	X	–	–	–	–	–	–	–	–
Elektronikas klubs	University	X	–	X	X	X	–	–	–	–	–	–	–	–
Fab lab	Private	X	X	X	X	X	X	–	–	–	–	–	X	–

Romania

If we speak about maker culture, Romania provided us with a set of exciting opportunities, but also with a set of difficulties. The maker movement has been slow in Romania, due to a number of reasons: there is still a small market for locally manufactured goods which always turn out more expensive then wide scale produced goods. "Making" as a hobby is often expensive and there is no widespread culture for that yet, but there is a curiosity and desire for it. The best thing is that in the last few years we can see a lot of new makerspaces that help young entrepreneurs to develop a new business in different fields. These makerspaces also help students and young employees to get access to a “working playground” that provides access to a wide palette of tools and equipment for digital fabrication and fast prototyping. These makerspaces work with universities to help students practice and develop new skills and experience in the working field.

Table 3. Makerspace overview in Romania

IDENTITY		ENGINEERING FIELDS						ARTISTRY/ MEDIA FIELDS						
Name of the Makerspace	Status	3D	Metal	Wood	Electronics	IT	Product design / Modelling	Painting	Audio	Photo / Video	Textile	Graphic Design	2D printing, stickers, badges, etc.	VR/AR/MR / Game Dev
NOD Makerspace	Private	X	X	X	X	X	–	X	–	–	X	–	–	–
Fab Lab Iasi	Private	X	X	X	X	X	X	–	–	–	–	–	–	–
Fab Lab	Private	X	X	X	X	X	X	–	–	–	–	–	–	–
Hackerspace Iași	Private	X	X	X	X	X	X	–	–	–	–	–	–	–
Rubik Hub	Private	–	–	–	X	X	–	–	X	–	–	–	–	–
Kult Hub	Private	–	–	–	–	–	–	–	–	–	–	–	–	–
Nest Hub	Private	–	–	–	–	–	–	–	–	–	–	–	–	–
Plan Zero	Private	X	–	–	X	X	–	–	–	–	–	X	–	–

Hatch Hackerspace	Private	X	X	X	X	X	X	–	–	–	–	–	–	–
Laborazon		–	–	X	X	–	–	X	X	X	X	X	X	X
Modulab	Private	X	X	X	X	X	X	X	–	X	–	X	–	–
Quib	Private	X	X	X	X	–	X	–	–	–	X	X	X	–
IncubArt	Private	X	X	X	X	X	X	X	X	X	–	X	X	–
Inventeaza	Private	X	–	–	X	X	X	–	–	–	–	–	–	–
Cluj Makerspace	Private	X	X	X	X	X	X	X	–	X	–	X	–	–
ToolHouse	Private	X	–	–	X	X	X	–	–	–	X	–	–	–

SWOT analysis

Project partners arranged interviews with 9 professors of subjects covered by makerspace, 9 HEI managers and 9 Makerspace managers from Lithuania, Latvia and Romania in order to better understand points of HEI and makerspace collaboration and organised round table discussions with 30 students in order to see how students perceive the competence development through the makerspace activities – what are the benefits, what is missing, etc. The outcomes of the interview and discussions are presented as SWOT analysis:

Strengths	Weaknesses
Impacts: – Tools and equipment available – Community feels less constrained to do maker activities – Community and like-minded people – Informal learning process – Peer2peer learning and teaching thus one can experience the satisfaction of sharing the skills, knowledge – Activities are nice socializing builder – Practical experience – Students better see connection between theory and practice – Experience, lessons learned what should be done in other way – Modernized study process – Networking with different people – Inspiration for new ideas, creativity, solutions for technical ideas – New skills, like teaching and technical – Greater comprehension about idea realization – Motivation to use theory in practical solutions – makerspace gives you the starting push – Students are more enthusiastic working on projects – Students have a closer relationship with the professors supervising the activities in the makerspace – Developed more interesting lab topics for students – Raised students interest and motivation **Benefits for a university:** – Less maintenance costs and more availability – More inclusion of different people with different skillsets	**Discouraging factors:** – Restriction or limited access to space (space for a project) – Limited access to makerspace (time) – Limited access to tools and equipment (not enough or fully booked also no equipment that fills the needs) – Excessive regulation and formalities – Different cultural values – Price/costs – Geographical distance/location – Low motivation of students – Low motivation of university management – Low involvement of business – Not sufficient of professional/diverse tools/equipment – Lack of time – Lack of materials – Safety – Security – Responsibility – The investment of time may not pay back due to the fact that a large part of people's activities are attending superficial interests and do not show the potential for long-term acquired skills – Lack of information, experience and academic knowledge – Too big projects – Difficulties to combine makerspace activities with study courses and all other parts of your life (for example a job)

– More innovation and opportunities for collaborative projects/activities – Involves students from different fields to work together – The incubator for the start-ups – It gives students opportunity to get acquainted with professional equipment – It would be easier for professors to explain with example – Plagiarism will decrease sharply – Increased creativity – Increased number of patents and commercialization – More higher skilled specialists – Higher student satisfaction and deeper interest in the industry – Better trained students, better feedback from industry, better resonance in society – "Materialization of knowledge" – Financial benefit – collaborating with the specific study field and businesses that also work in this field – Students solving the real life problems and having a better preparation for job market – Larger number of high school students will be interested in attending the technical universities – Students learn how to collaborate and organize their work – More relaxing work environment – New ideas, creative projects can be developed by students **Professors motivation:** – For professors it is a tool to innovate and update their teaching or educational content/material – Opportunities to have more interesting educational content via practical applications in informal makerspace environment – Sharing good practice between other universities/countries, – Encouragement from HEI managers – Better theory/practice rate in study process – Better infrastructure, accessibility, environment, availability of materials and instruments, interesting projects	– There are also examples when the staff is not too responsive – that discourages to work in a makerspace – New makerspace participants don't know how to start their learning process – Students do not take this creative space seriously enough – Charging for materials and for the use of tools and equipment – Rigid schedule/limited time access – Inefficient management of the makerspace – Lack of specialized training in new technologies – Little or no pay for university professors – Intellectual properties, copyrights issues **Drawbacks from university:** – Costs and effort of integrational processes with a risk that it won't reach the desired effect – Necessity of high investment – Physical and financial losses – Less time for theoretical lectures – Practically trained students start working for industry and do not complete their studies – To provide academic quality there should be a balance between theory, practice and soft skill courses – changes to be made in existing study programmes – Taking hobby-level projects can prevent attention from gaining knowledge of an industrial level – Tools, equipment, premises and additional staff for a makerspace make the studies more expensive – More practical courses in makerspaces mean that less students will participate in theoretical lectures – A project that is developed in makerspace should give a financial gain to the university; many of students projects do not give financial gain – Supporting makerspaces even more means that university has to decreased funds for other structures

– Professors can perform activities on their research projects along with students **Benefit for a makerspace:** – Sustainable support and funding – space, equipment, salaries for particular projects or programmes – Streams of young and active people who could become potential members – University can bring to a makerspace a strong background (working with suppliers, clients, partners, media) – Students to be involved in further activities and professional knowledge – Knowledge, professional specialists, development – Academic competence, knowledge and equipment – More funds and increase in flow of new participants – More contacts and experience – Attracting volunteers among the students, attracting talents for various contests – Recruiting students – Starting new business based on students' creative ideas – Developing projects along universities researchers and students – Sharing operational expenses – Makerspace can gain visibility and recognition if associated with a university – One possible benefit for a makerspace is the development and testing of new and creative ideas proposed by students **Collaboration methods:** – Students could perform their practice in a makerspace – Professors can give some lectures there – Students course projects can be implemented in a makerspace – Different national and international projects can be implemented together with a makerspace staff/facilities – A makerspace can through collaboration with a university attract suppliers/support, new clients and media attention	– Not everybody knows how to safely use the equipment in a makerspace – Bureaucracy – Difficulty to find a space within university for organizing a makerspace **Professors demotivation:** – Hard to academics who are specialized in narrow subjects/fields to adapt to a wider array of things happening in makerspaces though vice versa it can be also more engaging for them – it depends how they see it – as a way to expand their professional competencies or additional burden which requires them to step out from their comfort zone – Challenging for the professors with their "status" to adapt to a less formal point of view towards education and community based approached in makerspaces – Aging – Motivation – Responsibility – Lack of time – Financing model – Lack of understanding how these activities can help achieve their goals – Harder to evaluate tasks that have to be done in a makerspace – Conservatism **Students demotivation:** – Restriction or limited access to space, tools and equipment and excessive regulation and formalities – Low motivation of professors – Too little practice before entering the makerspace (missing self-confidence) – Low prospect from business – Not enough knowledge from staff – Not enough equipment – Complicated admission/participation process

- Industry could point out missing skills and university in collaboration with makerspace could give focused theoretical knowledge and practical skills
- Industry could point out problems and university in collaboration with makerspace could look for solution
- Cooperation with schools and students’ integration in research process
- Different contests, hackathons, thematic public events
- University could provide: space, equipment, personnel, makerspace could provide: materials, tools, components
- Developing common research projects can help supporting some of the operational expenses or acquiring new equipment
- Internship and using a highly trained supervisor for student’s activity

Studies attractiveness:

- The practical knowledge gained in collaboration with makerspace/students from different fields are essential in a labour market
- The study process is performed through projects supported by makerspaces
- The students need tools and equipment and they are coming to a makerspace because it’s cooler than a classic classroom
- A possible efficient way to collaborate could be that the university to offer the space and the large equipment and some tools, while the materials and components required for projects to be provided by the private makerspace

Students experience gained:

- Especially in project management and team working
- Gaining experience in collaborative work and developing hands-on experience
- Students will be better prepared to work in teams, to organize their work more efficiently and to manage a practical project

- Costs
- Inappropriate times
- Inconvenient location
- Fear of failures
- Lack of information
- Too much control, distrust
- Lack of competence for the use of equipment
- Activities are not included in study process
- Not wanting to develop a new idea - possibly fearing new things
- Fear to reveal a new business idea
- No direct connections with companies
- No projects
- Working environment is not friendly
- Students find themselves lost in reaching a solution to their problems

University administration demotivation:

- More responsibilities (as they see it)
- Not their typical way of managing things
- No experience
- Don’t understand the values/benefits gained
- Too much bureaucratic work with additional department/new activities
- Financial factors
- Safety risks
- Results not good enough (financial, knowledge and skills, motivation, new collaboration channels and projects)
- Intellectual property aspects

Makerspace demotivation:

- Loosing flexibility and freedom self-regulation
- Decrease in variety of projects and fulfilling the needs of all members
- Loosing innovation by becoming a service space for repetitive University educational programmes and needs
- Difficult to grow due to liabilities to university

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2017-1-LT01-KA203-035231

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	– Too much interest, lack of resources – Too intense flow – Bureaucracy, long chain of decision – Some rigid organizational rules
Opportunities	Threats
Opportunities of collaboration: – Integrating makerspace into educational programs – Training and keeping updated the staff (professors, lecturers) – Implementing various experimental and innovative projects which would help constantly update the educational programs – Organizational culture within the universities also help in their pursuits for innovation in education – Better possibilities to get governmental support – Better possibilities/chances when participating in international projects – Better possibilities to compete with other organisations – Better employability of students leading to higher number of new students and higher finances for a university – Better possibilities to be a policy-making organization – More projects with schools, industry and public sector – Promotion in schools – News in mass media – In society - the opportunity to create projects that can improve the accessibility of the environment and help people with special needs or in other ways improve quality of life – In political sense – solutions made in makerspace could help to develop the laws of the country (in specific fields and industries) – In economic sense - possibility to concentrate private investments to reach a specific target in terms of projects – In cultural sense – opportunity to make more open type activities – Circular economy and recycling projects – More focus on professional conversion – the student to get a theoretical preparation from university but also a practical training in makerspace, for example from local companies	**Political threats:** – It should be more or less an equal partnership, so this changing approach can be challenging – Bureaucratic – The decisions are top down, lack of consistency – If education and its usefulness are not a priority – Reducing education and science priorities – Bureaucratic and financial problems may arise – for example procurements and their retraction – Business monopoly may start to develop, which will lead to lobbying their own interests – Lack of understanding of the fiscal authorities regarding the activities carried in a makerspace – Political (governmental) instability could be a threat **Economical threats:** – Financial sustainability – Some of the main results/benefits of such collaboration can be quite intangible and hard to measure in financial metrics / KPIs – If there is no place to apply the skills and knowledge talents will leave country – Reducing funding for education – Risk of a financial fraud and money laundering – More unstable industries may lead to negative impact on society – Economic downturn – Supplementary taxation of the makerspace activities – No calls for projects dedicated to consortium/networks consisting of universities and makerspaces **Social threats:**

– More relaxing conditions for running the acquisitions required for operating the makerspace – More flexibility in hiring and paying competent personnel from universities – Focusing the activity of students more on practical aspects than theoretical knowledge – Developing and financing networks of makerspaces – Cooperation can be boosted if more people are aware of the advantages it offers **Advantages to the country:** – Innovation in education that needs to be elaborated and updated every day (or year) – Stronger maker movement leads to higher quality of education, stronger labour market, better international recognisability – More entrepreneurs – Increased development of new products and technologies – In longer period, high added value products and businesses – Society would get higher quality specialists, that would have larger field of skills and would have higher creativity, therefore leading to more innovations – More new companies and businesses would be established, which leads to more workspaces for society and therefore a rise of GDP – Environment of innovations would develop, and more investments from other countries could be attracted, therefore leading to rising competitiveness of the country in the global market – A synchronization of the graduates with the needs of the job market – Tax cuts/deductions if a company finances a makerspace – Students better prepared for the challenges implied by the advancements in technology, more creative and enthusiastic, able to integrate faster and more efficiently in companies **Skills for the staff:**	– The traditional point of view/perspective and organizational culture/values of Universities could differ from less formal and more open-minded private makerspaces – Stereotypes about the academic environment and professions – Youth demotivation caused by the decline of the prestige of the technical industry in the eyes of the public – Pressure and denial from society – disbelief in ideas – Stereotypes and lack of information – Unsuccessful collaboration with schools (which could be caused by not showing the practical skill enough) – The increasing emigration of graduates – Different perspectives over the educational activities **Threats from external environment:** – Changing environment, competition – Not enough support from governance on maker movement, start-ups, business – Not sufficient information for public on maker movement and advantages of makerspace-university collaboration – Reduced funding for universities – SMEs not budgeted for collaborative projects – Inconsistency in communication between the city and the makerspaces – Unwise action from managing authorities – Lack of a governmental strategy for start-up accelerators and hubs – Too little publicity for raising the awareness among professors, students and decision actors

– Systemic approach, expands vision, flexibility, interdisciplinary approach, cooperation, networking, new products development, break down age barriers – New experience, additional knowledge, different point of view, broader point of view – Learns to speak in the same language with the younger generation – Pedagogical skills, management, time management, communication – Entrepreneurial and project management skills – Improve technical innovation, increase the number of innovative start-ups – Collaborative work skills, hands-on skills, exchange of knowledge – Establishing new forms of cooperation, new research approaches **Caution acts:** – Legal documents from governance, dissemination of information to public, transfer of best practice from abroad – Political decision about development directions – Communication with the public sector – Attract suitable makerspace managers – Good education for kids and students about makerspace movement – More workspaces – more opportunities to learn practically	

Collaborating parties: HEI and a makerspace

The relationship between a higher education institution (HEI) and a makerspace can be threefold: HEI and fully owned makerspace, HEI and co-owned makerspace, HEI and a private makerspace. The first one is the most resource intensive for a university and usually the most integrated into study process. The second one is a joint venture between a university and external partner (i.e. business company). The third one is a relationship between a university and a fully independent private makerspace.

Chris Anderson, CEO of 3D Robotics, and former Editor-in-Chief at Wired once said about a private makerspace TechShop: “It’s the same revolutionary innovation model, but now applied to one of the biggest industries in the world—manufacturing.” Robert Scoble, Startup Liaison Officer at Rackspace said “TechShop is the garage that Thomas Edison wished he had”. These are all praise for the once successful network of private makerspaces. Once successful, because TechShop filed bankruptcy in 2017.

This is not the first time we see a private makerspace business collapse. But that only implies that this sort of business is risky for private bodies. Perhaps this model fits better in a safer environment where it generates other “profits” such as innovation and creativity rather than money. After all, the first makerspace was opened in a university by a group of students of MIT in 2001 (Barrett et al. 2015).

Certain characteristics of a makerspace can promote innovation in universities.

Two important basic elements that lead to more innovation in a makerspace are intrinsic motivation and unstructured activity, and these elements are distinct from much of the university experience (Iscenco 2015).

Intrinsic motivation, as opposed to extrinsic motivation, refers to behaviour that is driven by internal rewards rather than rewards coming from another source.

It has been shown that intrinsic motivation is important for increased innovative thinking (Pink 2011, Sawyer 2008).

A second intangible element of university makerspaces that are trying to produce innovation is unstructured activity (Sawyer 2008). Again, most university activities are highly structured. Students are given very specific structured assignments. The student is told to solve a few specific, well-defined problems, usually culled from a textbook, in a specified amount of time. The problems are sorted by chapter so the student knows which techniques to apply. Each problem will generally have exactly one correct answer. The same goes for the professors them-selves and all the other university staff. Their work is very structured and bureaucratic leaving little space for creativity or innovation. A makerspace on the other hand, provides atmosphere and infrastructure with complete freedom of action.

Innovation, by definition, is not structured. Innovation requires new approaches to problems that are different than previous approaches.

Substantial evidence suggests that the culture of an environment has a significant impact on the amount of innovation that is produced (Johnson 2011, Weiner 2016).

The role of culture is also highlighted in research on makerspaces, especially through the sense of community makerspaces promote and nurture: “Participants often refer to the space as feeling like a family or group of friends” (Sheridan et al., 2014, p. 528). Makerspaces support or generate a community of practice where members share knowledge, experiment, and work together on innovative projects.

The situated learning perspective proposed by Lave and Wenger (Lave, 1991; Lave & Wenger, 1991) expands experiential learning approaches because it emphasizes the social component of learning, described as "an integral, inseparable aspect of social practice" (Lave & Wenger, 1991, p. 31). It reconceives learning as a sociocultural practice whereby students learn through practice and ongoing interactions with other students, faculty members, or professionals who have more expertise. Situated learning entails legitimate participation to a specific community of practice defined as a group of people "that have been practicing together long enough to develop into a cohesive community with relationship of mutually shared understanding" (Lave & Wenger, 1991).

By shifting the focus of learning from the individual cognitive development, to learning as a sociocultural practice, the situated learning perspective provides us a useful lens to understand how makerspaces might support the development of an innovative and entrepreneurial students. But very importantly, it also provides a relevant model to design a community of practice that can allow newcomers to engage in peripheral participation and eventually become core members of the community.

The premise of this paper is that these innovation-promoting characteristics can be identified and implemented (although imperfectly) so as to increase the output of innovative ideas.

Good practice examples

DTU Skylab	
Location	Diplomvej 373A Kongens Lyngby Denmark
Contacts	http://www.skylab.dtu.dk https://www.facebook.com/dtuskylab/ +45 93 51 13 96
Collaboration type	HEI and fully owned makerspace DTU Skylab is the innovation hub located at Lyngby Campus at DTU, Technical University of Denmark
Opening date	1 March 2013
Tools and premises	Prototyping workshops, meeting rooms, work stations, event rooms, lounge and kitchen.
Activities	DTU Skylab is the innovation hub located at Lyngby campus at DTU, Technical University of Denmark. The activities are focused on enabling student innovation and entrepreneurship through three main focus areas: student innovation, company collaboration and academia. Student innovation include everything from smaller student projects, case solving on courses and student start-ups. **Connecting theory with real world** They believe that students learn and advance better when combining theory and practice. This is why they facilitate the connection between companies from the public and private sector with DTU students. It is also important for them to build bridges between student innovation and the academic world hence their third focus area; academia. **Think big - fail fast** They support the student innovation practically by providing free access for all DTU students to all the workshops; metal, wood, welding, rapid prototyping (3D printing, laser cutting and 3D scanner), electronics, design lab, wet lab and FoodLab. The DTU Skylab workshop crew is highly specialized and can assist on small and big projects. It is their philosophy that DTU Skylab empowers students to think big, fail fast and then scale quicker. This room-for-error culture supports students to dare to think ambitiously, fearlessly and globally. **Sharing connections and network** DTU Skylab values diversity, interdisciplinary and cross-cultural collaboration, and this is why they work closely together with both domestic and international partners to knowledge share and strengthen the network by sending both employees and students out to expand the current network and bring back significant, new findings.
Story	DTU Skylab, back then DTU Innovatorium, opened on 1 March 2013 in a prototype version in building 205 on Lyngby Campus. The aim was to support student innovation and entrepreneurship at DTU providing an exciting and creative environment where students could test their innovative ideas, share knowledge and collaborate with external partners and the business community.

The strategy was just to get started and then learn by the mistakes along the way. They tested the concept for about a year and it became a success. DTU Skylab has proved that the right mindset, the right facilities and the right network make up the perfect combination for helping students convert their ideas and concepts into useful societal input. Several students went from idea to product to start-up or created positive results through their work with innovation projects in existing companies. It was then decided that a new version 2.0. was to be created. In collaboration with the users of Skylab, Skylab version 2.0 was created on 1 September 2014. The new DTU Skylab is to help set the agenda for innovation and entrepreneurship.

Photos (source: http://www.skylab.dtu.dk)

Aalto Design Factory

Location	Betonimiehenkuja 5 C, 02150 Espoo, Finland
Contacts	https://designfactory.aalto.fi/ https://www.facebook.com/aaltodesignfactory
Collaboration type	HEI and fully owned makerspace ADF was the first official building of Aalto University
Opening date	3 October 2008

Tools and premises	Prototyping workshops (3D printing, vinyl cutting and large scale plotting; Electroshop; Electronics and programming; Machineshop; CNC, metalwork and modelling); meeting rooms, open spaces, kitchen. ADF operates in an old wood research laboratory which has been designed to support experimentation, prototyping and interaction. The multi-purpose nature of the spaces makes it possible to maintain a high rate of use and keep things flexible. It's all about the people. The community consists of researchers, students and staff from different schools of Aalto University, entrepreneurs and company representatives.
Activities	
Story	Aalto Design Factory was born from a research project focused on creating an ideal physical and mental working environment for product developers and researchers. Today ADF is one of the spearhead projects and one of the first physical manifestations of Aalto University encouraging and enabling fruitful interaction between students, researchers, and professional practitioners. Design Factory is an experimental co-creation platform for every single person of the Aalto University community, as well as for its partners. The only constraint is that the actions taking place here should promote better learning, better research, or better interaction between the university and the society. Design Factory Global Network members operate based on the same philosophy and principles and provide familiar DF-environment for their local community. The goal is to be the leader in international university collaboration beyond academic boundaries.
Photos (source: https://designfactory.aalto.fi)	

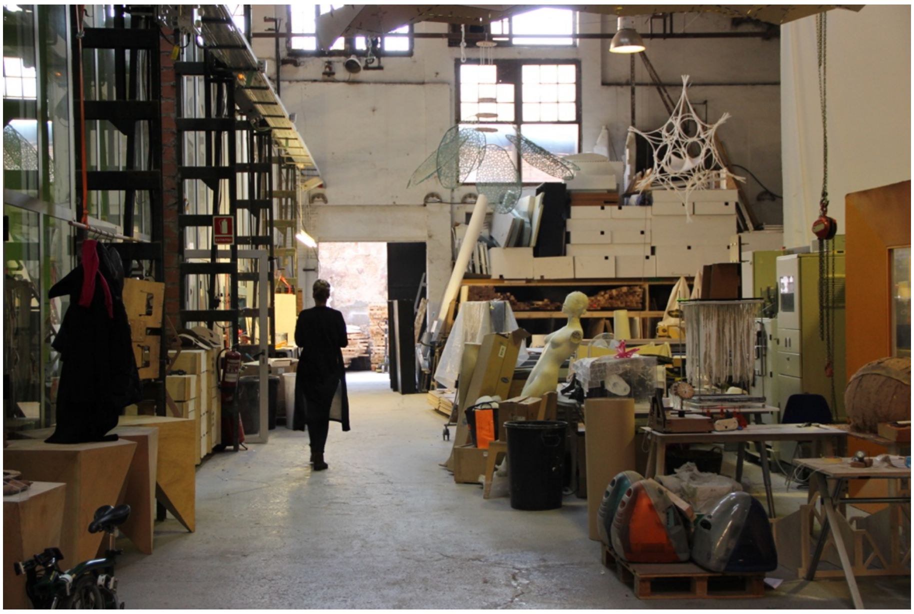

AALTO DESIGN FACTORY
Aalto University
Design Factory
All you need is...
Love, Design, Business and Engineering

Fab Lab Barcelona

Location	Pujades 102 08005 Barcelona, Spain
Contacts	https://fablabbcn.org/ https://www.facebook.com/FabLab.BCN/ +34 933 20 95 20
Collaboration type	HEI and fully owned makerspace Fab Lab Barcelona is part of the Institute for Advanced Architecture of Catalonia, where it supports different educational and research programs related with the multiple scales of the human habitat.
Opening date	26 March 2007
Tools and premises	Fab Lab Barcelona includes the following machines: a laser cutter that makes 2D and 3D structures, a sign cutter that plots in copper to make antennas and flex circuits, a high-resolution CNC milling machine that makes circuit boards and precision parts, a large wood router for

	building furniture and housing, and a suite of electronic components and programming tools for low-cost, high-speed microcontrollers for on-site rapid circuit prototyping.
Activities	Fab Lab Barcelona is the headquarters of the global coordination of the Fab Academy program in collaboration with the Fab Foundation and the MIT's Center for Bits and Atoms; the Fab Academy is a distributed platform of education and research in which each Fab Labs operates as a classroom and the planet as the campus of the largest University in construction in the world, where students learn about the principles, applications and implications of digital manufacturing technology. FabLab Barcelona also runs programs such as Fab Kids (educational activities for children)
Story	Fab Lab Barcelona is part of the Institute for Advanced Architecture of Catalonia, where it supports different educational and research programs related with the multiple scales of the human habitat. The mission of the Fab Lab is to provide access to the tools, the knowledge and the financial means to educate, innovate and invent using technology and digital fabrication to allow anyone to make (almost) anything, and thereby creating opportunities to improve lives and livelihoods around the world.

Photos (source: https://fablabbcn.org/)




MAKERY

Recommendations on HEIs and makerspace collaboration

What makes the makerspace a place everyone wants to visit?

- Makerspace members see the variety of tools and equipment as a big advantage
- Non-formal, cosy environment stimulates creativity
- A makerspace community is a necessary for consultations, sharing experience, learning and teaching in peer2peer way
- Students appreciate learning through practice
- A makerspace should involve additional activities and events not directly connected to maker activities (such as technologies and prototype exhibitions, competitions, presentations on funding opportunities, entrepreneurship; concerts, meetings etc.)
- A makerspace should create a network for the members and help them to connect stakeholders
- A makerspace is usually a place which works as an inspiratory for new ideas and technical solutions. The creator of a new makerspace has to think about that
- The environment of a makerspace has to help students to access professors easier, to communicate more informally
- The topics developed in a makerspace have to be modern, engaging and practically applicable
- Try not to limit access to a makerspace (rooms, tools, know-how)
- Reconsider the prices to be reasonable
- Check your makerspace location: how to make it easier accessible by public transport/car/bike/foot
- Be sure you have discussed the safety and security issues
- Clearly share the responsibilities between staff
- Be sure that every visitor is welcome
- Create strong management team (being able to delegate effectively, to bring out the best in others, proactively detecting and resolving problems, unifying teams, willing to learn from the team, etc.)
- Take inspiration from good practice examples
- Educate kids and students about makerspace movement
- Raise awareness
- Invest time and effort into public relations/marketing in order to create an attractive space

How to get the highest value for a university?

- Be sure you will ensure sufficient funding for a makerspace
- Create interdisciplinary projects, let and motivate professors learn from each other

- Let the students understand how different subjects are connected and depending from each other
- Convince professors to learn from students. Involve students in equipment maintenance activities, accept students' internships in the makerspace
- Do not limit the creativity
- Involve stakeholders in students' projects
- Provide spaces for start-ups, foster them and give consultations
- Give lectures on entrepreneurship and commercialisation to increase the number of start-ups
- Invite professors to implement real projects and teach how to apply theory in practice
- Take into account the labour market needs to prepare the qualified specialists
- The cosy makerspace with a strong technical and knowledge base will help to increase the number of students
- Involve business in the product development and get financial benefit in this way
- A relaxing environment will help to work for unlimited time
- Let professors use the modern tools and they will be motivated to update their teaching or educational content/material
- Share experience with other universities and/or countries
- Motivate professors for additional activities
- Update study programmes by involving more practical/hands-on activities
- Involve students in the research projects
- Ensure that professors will be paid for additional tasks

How to get the highest value for a makerspace?

- Collaboration with a university can be a sustainable support and funding – space, equipment, salaries for particular projects or programmes
- Involve university students in makerspace activities
- Use university's contact base
- Get university's support letters when communicating with suppliers, clients, partners and media
- Increase your visibility and recognition through university
- Employ students as they can strengthen the collaboration with a university
- Use professors' academic competence creating your projects
- Strive for funding making common projects with a university
- Offer students internship opportunities

- Bring together students and business for the efficient results
- Share operational expenses with a university
- Be sure that the projects you are developing are not too big/too expensive (in the other way the staff could lose their motivation)
- A makerspace should have enough freedom for a self-regulation
- Plan the workflows

How to collaborate?

- Offer students internships
- Perform lectures in makerspace premises
- Make students course projects with makerspace tools
- Prepare national and international project applications
- Invite university representatives and makerspace representatives when communicating with suppliers, clients, media
- Focus university theoretical lectures and makerspace practical tasks on industry needs
- Suggest different problems solutions for industry
- Involve schools to participate in preparation of young specialists
- Perform research projects in the makerspace, invite university students
- Organise different contests, hackathons, thematic public events
- Share your input: university could provide space, equipment and personnel, makerspace could provide materials, tools and components
- Create multidisciplinary teams
- Offer experience in collaborative work and developing hands-on approach
- Continuously train your staff
- Integrate makerspace in educational programmes
- Use innovation (new technologies, new tools and innovative thinking) in education
- Implement projects with schools, different universities, industry and public sector
- Promote international cooperation projects, with outcomes that are important in all levels
- Increase the accessibility of the tools and activities for people with special needs
- Provide public/open activities
- Cooperate and create networks
- Discuss the regulations. Be sure they will not slow down the processes (contracts, procurements, employment, financial issues, etc.)
- Clear vision/understanding of both sides

- Things to be taken into account: the need of time to work it out as it can be a constant process thus it needs to stay flexible, innovative and adaptive to changing needs

Higher intentions

- Promote maker movement with the aim to achieve higher quality of education, stronger labour market, better international recognisability
- Develop new products and technologies
- Create high added value products and businesses
- Grow higher quality specialists, that would have larger field of skills and would have higher creativity, therefore leading to more innovation
- Educate students better prepared for the challenges implied by the advancements in technology, more creative and enthusiastic, able to integrate faster and more efficiently in companies
- Foster the development of the new companies and businesses, which leads to more workspaces for society and therefore a rise of GDP
- Create innovation to attract more investments from other countries, there for leading to rising competitiveness of the country in global market

Conclusions

Makerspaces are rather new phenomena in HEIs and not sufficiently exploited. It is challenging to find and use good practice examples, since each and every makerspace is unique. They differ vastly in size, governance, funding structure, theme, etc. Rapid prototyping is an integral part in most makerspaces, although the upcoming trend of media workshops in makerspaces and interdisciplinary projects with strong digital core has been discovered: photo & video studios, graphic design, virtual reality labs are increasingly integrated in makerspaces.

The elements that lead to innovation and creativity boost in a makerspace are intrinsic motivation, unstructured activity and community culture, which are distinct from the usual university experience. All in all, it is evident that the partnerships of higher education institutions (HEIs) and technical spaces (makerspaces) boost innovation and creativity, leading to trans-disciplinary approaches and new teaching methods in HEIs, availability of open resources for formal and non-formal education, better entrepreneurial and creativity skills of graduates, wider opportunities for private makerspaces and increasing the resource base of both parties.

Major limitations of research include:

- Various definitions and self-appellations
- Vast lexical field
- Numerous labels and communities gathering different structures
- Hard to find enough information
- Limited presence on social network
- Apparently, no possible rule of proportionality to draw between the makerspace size and its online presence
- Importance of watching the posted online photos to have a broader idea of the structure (material, personnel, events…)
- Inaccurate information
- Websites and data not updated or not as much as it should be.

These guidelines were prepared as a part of an ERASMUS+ project HEI Makers #2017-1-LT01-KA203-035231. The aim of the guidelines for higher education institutions is to specify how they can (better) utilize rapidly expanding technical spaces (like Makerspaces, FabLabs, Techshops, etc.) for the purpose of higher quality of education and more relevant graduate skills. Based on the examples of Lithuania, Latvia and Romania, it aims to help HEIs in Europe to understand the principles of strategic integration of makerspaces into study process, get familiar with definitions and quality standards, adapt frameworks for recognition of learning outcomes, join the network of HEIs which run / collaborate with makerspaces.

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