Roll out Strategy

D.T3.3.2 StrojLAB – PP5 CZ 02 2019

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1. Incorporation of innovative services and tools to your portfolio

1.1 Chapter 1 – Background

Fablab at the Faculty of mechanical Engineering of Brno University of technology began to form in 2015 within the Reverse Engineering and Additive Technologies Division of the Department of Mechanical Engineering. The global vision was to create environment where students could realize their ideas and produce real things by themselves, where they could get new practical-oriented knowledge and experience with innovative technologies. The University fablab was to serve as extension of regular (predominantly theoretically oriented) lectures. This should be beneficial not only for the students, but also for the University itself in finding talented students with the potential to continue their creative work within the post gradual study. Creative work of students should attract the interest of companies and start-ups and bring interesting projects in cooperation with industry.

At the end of 2016, the team around the fablab became a part of FabLabNet Interreg project. During the following years University fablab - StrojLAB – was equipped and implemented into University life. Fablab have been equipped with various 3D printers, a laser cutter, a hand-helded 3D scanner, vacuum shaping technology and electrotechnical and workshop tools. The lecturers and staff of the StrojLAB created public websites which present equipment, operating rules and provide video tutorials for each machine: https://www.StrojLAB.cz/. For advanced students StrojLAB offers training of 3D metal printing, metrology 3D scanning, photogrammetry measurement or the 6-axis KUKA robot.

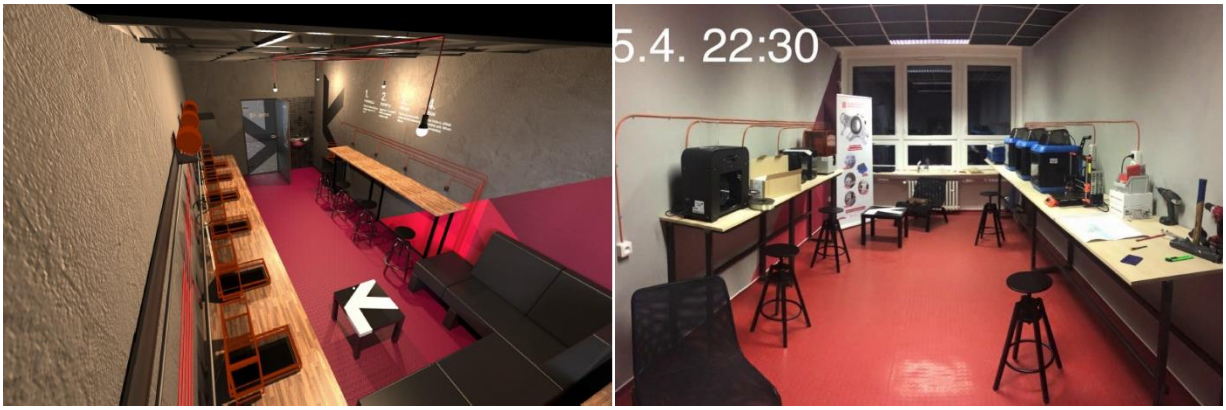

Figure 1: 3D documentation of the future StrojLAB on the left, StrojLAB in its real state on the right.

During the FabLabNet lifetime, StrojLAB had a great opportunity for experimenting, various tools for engaging audience and promoting the role of StrojLAB in stimulating the bottom up innovation. StrojLAB was part of many public events and organizer of FaBfest I and II:

- April 2017 – Autodesk Academia Design - Competition for student in 3D printing
- September 2017 – MSV Brno
- September 2017 – Additive Fabrication Forum
- March 2018 – Fabfast I – Introduction of StrojLAB, the BUT fablab
- June 2018 - Maker Fair Prague
- October 2018 - Night of scientists
- November 2018 - FABfest II – Competition for Mechanical designers + Festival Prototyp

Important milestones were implementation of non-frontal education using workshop and equipment of StrojLAB into the portfolio of subjects of bachelor study and the start of collaboration with students' competition and development teams at the Faculty of mechanical engineering via PILOT activities I and III:

Pilot I: Mentoring program was done during the winter semester of academic year 2017/2018. Overall 3 student teams participated in the program: Formula Student Team – TU Brno Raing, Pneumobil Racing Team Brno and Aircraft Builders Team. At the beginning of the program, students chose the topic of the project which was interesting for the further development and competitiveness of their team. E.g. faster fabrication of components or additive design enabling more complex shapes. The mentoring program itself consisted of three phases: initial training, project design and project prototyping. Firstly, the students passed the courses relevant to the chosen project topics. Then, during the design phase, mentors led the students to successful implementation the knowledge gained during courses into the manufacturable prototype. Third phase was manufacturing of designed prototypes using StrojLAB equipment with assistance of mentors. Each student team finally produced one prototype.

The mentoring program was perceived by students as a useful and effective way to get acquainted quickly with the technologies needed to make their own prototypes. We found out, that if the real prototype is to be produced, the timing of the design and prototyping phase need to be continually adapted. Not all prototypes were in expected state in the end of the activity, however, additional work beyond the scope of the program ensured their full completion. Students expressed their interest to extend the portfolio of technologies and equipment, because some of their ideas could not be realized.

Pitot III: The Fablab implemented novel non-frontal education based on project learning system directly into education program. The aim of the subjects is to learn theory and practically improve the knowledge via projects. The projects cover digital technologies, CAD,

FEM, tribology and technical diagnostic. Outcomes of subject are typically functional mechanical mechanisms, devices, prototypes. Fablab supports the implementation of student's semestral projects and diploma projects within the subjects: Team Project (FSI-ZKP), Mechanical Design Project (FSI-ZIP), Engineering Project (FSI-ZKR), Diploma Project II (M-KSI, M-PDS) (FSI-ZD5), Machine and Process Control (FSI-ZAE). Fablab has been implemented into Master's study program subjects as project learning support. Students use Fablab equipment to design and implement functional products. Costs of material are sponsored by Institute of Machine and Industrial Design.

Tools that were beneficial in the portfolio of Fablab Brno:

Public events were contribution for creating community around the Fablab Brno by presenting its activities to wider audience. Fabtalks helped to promote Fablab Brno and develop cooperation with companies. Mainly start-ups and young growing companies were interested in working with students in the field of development (i.e. Formula student) or finance support. Activities in PILOT I brought stable cooperation with students' teams of Formula Student Team – TU Brno Raing, Pneumobil Racing Team Brno and Aircraft Builders Team. Non-frontal education supported by StrojLAB within Pilot I and III have following benefits:

1) to the students:
   - deeper practical knowledge's
   - experiences with innovative technologies
   - team work and cooperation
   - project planning skills
   - presentation skills
   - more interested and motivated students
2) for the University growth:
   - increasing competences of staff in project-oriented education
   - closer relationship between lectors and students
   - space and equipment for realization of innovative student projects
   - commitment to development, research and innovation brings more talented students to post gradual study

New tools/services that would be beneficial to implement in your portfolio of services:

1) extended portfolio of tools and equipment
2) larger space of workshop
3) management and administration of StrojLAB should gradually move to the hands of the student community
4) fablab network as part of the student's mobility

1.2 Chapter 2 - Goal and expected outcomes

1) extended portfolio of tools and equipment

During the Pilot I and III some ideas of students could not be implemented due to limited portfolio of technologies. Students would appreciate mainly a 3D printer with a larger building space, a sheets metal cutting plotter, or a milling machine. This equipment allows to realize more complex projects. We try to support continual development of our StrojLAB as an important factor for maintaining the interest of students.

2) larger space of workshop

The StrojLAB is aimed to support all students of the faculty which has around 1000 participants. However, StrojLAB workshop has quite a small floor area (21 m^2). This strongly limits the number of students involved, number and scope of projects realized in it, and portfolio of equipment. Given that the StrojLAB community is still growing, it leads to the idea of expanding existing facility.

3) the student community should take responsibility for Strojlab management

Managing of the StrojLAB is time-consuming and it never be able to carry on without financial support. The time of lecturers and financial costs can be reduced by higher involvement of students in the management process. Several students should take the responsibility for managing StrojLAB under auspices of a lecturer. The lecturer should only provide supervising and support. Students should develop their own initiative in communicating with experts and companies. They should be able to look for finance support of their projects from the side of industry; to invite external mentors and organize seminars according to their needs.

4) Fablabnet as part of the students' and lecturers' mobility

Our vision is to support mobility aimed on project realization and practical experience of the lecturers and students. The exchange would enable to realize projects using equipment, which are not available at home University. The lecturers and students would have chance to learn about the management of other fablabs or gain experience with other technologies. This would support internationalization of the education and improve team work, language and practical skills in mechanical engineering.

1.3 Chapter 3 - Target groups

The StrojLAB is aimed to support all students of the faculty which has currently around 1000 participants. In the future period, we would like to increase the students' and lecturers' mobility connected with projects and education realized using StrojLAB. Our target group would be than expanded by foreign students and lecturers. This would support

internationalization of the education and sharing of knowledge among the students from different countries. It would also improve team work, language and practical skills in mechanical engineering and.

1.4 Chapter 4 - Content of the action

1) **extended portfolio of tools and equipment**
   During the following 2 years we will try to get funding either from the faculty or via project support for earning new equipment. We will choose the equipment according to the needs of students and select suppliers with the best price offers.

2) **larger space of workshop**
   The long-term plan of the faculty is to support the development of StrojLAB and to provide a newly reconstructed room. In the horizon of 2 years the new room should be gained and furnished. We are convinced that a team of staff and student volunteers will do everything necessary to complete a new place if the faculty provides the room.

3) **the student community should take responsibility for Strojlab management**
   We plan to organize an event for the purpose of introducing StrojLAB to the new students every year. The event will also serve to find students for StrojLAB administration. The students will be motivated by the benefits connected with the usage of machines and StrojLAB access. The system of management, competencies in the administration and expected outcomes will be clarified and written. The competences in administration will be divided into those assured by students and those by lecturers:

   Lecturers:

   - Supervision of students in administrative positions at Strojlab
   - Approving finance for sustainability of StrojLAB
   - Approving and supervising the events organized by students with external experts
   - Collecting incentives to innovate StrojLAB

   Students:

   - Routine maintenance of equipment and reporting serious defects of equipment
   - Managing access to StrojLAB and enforcement of rules
   - Look for potencial industry partners for finance support of the projects
   - Inviting external mentors and organizing seminars according to their needs (under the supervision of lecturer)
   - Providing training to the new members and share of the knowledge

5) Fablabnet as part of the students' and lecturers' mobility

We aim to find a finance support for short exchange of students and lecturers among European fablabs. It seems that our vision correlates with the focus of the project Vulca. The project is led by Alex Russellet and currently is in pre-implemantation phase. In 2019 it begins with twelve mobility experiences throughout Europe. After visiting 250 communities, they have come with the conclusion that European Makers' Mobility is possible, but not without its difficulties. That is why currently Vulca wants to gather all the people driving this mobility to discuss how to facilitate this mobility. All the panellists that the Vulca project bring together, and all the workshops that they organise, will aim to create an opensource mobility guide for maker(space). StrojLAb is in favour of these activities and would like to be one of the users of the guide.

1.5 Chapter 5 - Timeline

Described activities will be implemented from 2020 over the next 4 years. Some of them are strongly dependent on the external factors such as finance support, support of students, lecturers and the faculty.

1.6 Chapter 6 - Budget

Human resources:

- 2 lecturers for supervision of students and management – each 0,2 FTE
- 2 students in management of fablab – each 0,2 FTE

Capital:

- 3D printer with a large building space
- sheets metal cutting plotter
- milling machine

Consumables:

- maintenance of equipment
- filament for 3D printers and material for other machines
- common equipment intended for a new room

Category	Entry	One-time purchase €	Annually €
Human resources	lecturers 0,4 FTE		7 500
	students 0,4 FTE		3 700
Capital	3D printer with a large building space	6 000	
	sheets metal cutting plotter	8 000	
	milling machine	8 000	
Consumables	maintenance of equipment		2 000
	material for 3D printers and other machines		800
	furnishing of a new fablab room	3 200	
Totally		25 200	14 000

1.7 Chapter 7 - Assessment of the environment

	Helpful - to achieving the objective	Harmful - to achieving the objective
Internal Origin - attributes of organization	• Support of the department of mechanical design • Support of the faculty • Stable target group • Regular events for propagation and advertisement • Technical knowledge and experience (RIAT research group)	• The Faculty will not provide suitable premises • Students will not be willing to work in Strojlab administration • Low interest in the participation of lecturers without financial support
External Origin - attributes of environment	• Strojlab is part of existing net of fablabs - • Partners in Fablab Brno in potencial projects • Growing maker community in Czech rep.	• External financial support not obtained • Project Vulca will not be supported

1.8 Chapter 8 - Cooperation

We plan to stay in touch with Alex Russelet and support his attempt to create a mobility guide for maker(space). We want to keep in touch with the fablabs which were involved in the Intereg project and would like to include these fablabs in the project of lecturers' and students' exchange. We plan to cooperate with Fablab Brno on events for public and students as in the past.

1.9 Chapter 9 – Advertisement

We plan to organize an event for the purpose of introducing StrojLAB to the new students every year.

2. Earning official academic credit for Fablab education programs

2.1 Chapter 1- Background

After an analysis of the current situation regarding the subjects that are offered in our region (Czech republic) and that have similar content to a course that we would like to offer, following results revealed:

- Subject **Additive Technology** at Faculty of Mechanical Engineering, Brno University of Technology. This subject gives the students the theoretical foundation that is practiced during seminars and laboratories and is focused in plastic and metal additive technologies, their overview and detailed information and practical knowledge. The theoretical knowledge is focused in processing of plastic materials in FDM and SLS machines and especially metallic materials (e.g. aluminum, titanium and stainless-steel alloys) in SLM machines but also in testing of samples produced by this technology. After completing this subject, students obtain 5 credits in ECTS system. At this time the subject is taught only in Czech language and it is one semestral subject. Source: https://www.vutbr.cz/studenti/predmety/detail/186705
- Subject **Machine Design - Mechanisms, 3D Print and Solidworks** at Faculty of Mechanical Engineering, Brno University of Technology. This subject is composed of lectures, seminars and laboratories. During the lectures, students are introduced to the common mechanisms and their principles. During the seminars, students get familiar with the technology of 3D printing (especially FDM technology) and with Solidworks CAD software and during the rest of the seminars and laboratories they are supposed to design and build simple machine using selected mechanism. After completing this subject, students obtain 4 credits in ECTS system. The subject is taught only in Czech and it is one semestral subject. Source: https://www.vutbr.cz/en/students/courses/detail/188816?apid=188816
- Subject **3D Print** is taught at Faculty of Information Technology, Czech Technical University in Prague. This subject is focused in FDM process of additive manufacturing technology, design of the parts for 3D printing, preparation of the model (slicing) for 3D printing, building of 3D printer and 3D print process itself. After completing this subject, students obtain 4 credits in ECTS system. The subject is taught in Czech and also in English and it is one semestral subject. Source: http://3dprint.fit.cvut.cz/vyuka
- Subject **Additive and Alternative Technologies** at Faculty of Mechanical Engineering, Czech Technical University in Prague is part of the study programs called Industry 4.0 and Manufacturing Engineering. Content of the subject is composed of information about technologies for additive manufacturing of plastic and metallic materials, machines used for this type of manufacturing and their design, optimization of the additive manufacturing process and its simulation, etc. After completing this subject, students obtain 4 credits in

ECTS system. The subject is taught in Czech and it is one semestral subject. Source: http://bilakniha.cvut.cz/cs/predmet5537306.html

- Subject **Additive Technology** at Faculty of Mechanical Engineering, Technical University of Ostrava. During the subject students are introduced to the basics of modeling and preparation of the models for 3D printing and they are introduced to the prototype fabrication with FDM and SLM technologies with respect to topological optimization and design of bionic structures. After completing this subject, students obtain 4 credits in ECTS system. The subject is taught in Czech and it is one semestral subject. Source: https://edison.sso.vsb.cz/cz.vsb.edison.edu.study.prepare.web/SubjectVersion.faces?version=346-0001/01&locale=cs

As can be seen from the previous list of subjects, there are several subjects that offer similar content to the course **3D metal printing - Additive technologies in mechanical engineering** that we want to offer, but there are several limitations. Firstly, except for the subject **3D Print**, all of the subjects are taught only in Czech and this mentioned subject covers only the field of FDM 3D printing, not metal printing. Secondly, all of the subjects are taught as one semestral, which means that there is a need for at least 12 weeks to finish them.

The new course is beneficial from several perspectives. Firstly, it covers interesting and progressive field of 3D metal printing which is getting more and more attention and is applied in expanding list of industries. Secondly, closest to the course is the subject Additive Technology at Brno University of Technology, which is however not taught in English, which is significant limitation for any foreign applicants. Thirdly, this course can be completed in two to three days, depending on the type of the course (basic/advanced) compared to 13 weeks subject, which is beneficial especially for foreigners who are not able to spend longer time period.

2.2 Chapter 2 - Vision and Goal

- Our vision is to have people well-educated in the technology of metal additive manufacturing, excited for this technology and its integration into the manufacturing businesses, prepared for the employment for a post in such a company or to start their own business in this field.
- Our goal is to attract people from the Czech Republic (also from more distant regions of CZ) and across the Central Europe to metal additive manufacturing as a progressive technology by offering this education program. Our goal is to increase the knowledge of the people by getting through the training of metal additive manufacturing where they will have a chance to obtain theoretical knowledge of metal 3D printing in general and more specifically of selective laser melting and also the practical experience of the processes necessary for preparation of the manufacturing and also for the postprocessing of the parts. The goal is also to increase employability of the participants of the education program as there is

increasing number of companies that start to work in the field of metal additive manufacturing. This program could also be interesting for people who are considering setting up their own business in this field.

- The outcome of this program are people educated in the metal additive manufacturing and related processes.

2.3 Chapter 3 - Expected outcomes

- Participants of the education program should after completing the program:
  - know what are the technologies of metal additive manufacturing, where they are used what are the benefits of each technology and what are the drawbacks.
  - understand the process of selective laser melting (SLM), influence of the main process parameters, strategies used in the SLM technology and typical malfunctions
  - be able to prepare the data for the manufacturing process, orient the part in the building chamber, prepare the supports for the part, set the process parameters, prepare the material used for the manufacturing, prepare the machine, remove the model from the platform, remove the supports and treat the surface of the part.
- There is a need for well-educated people in the field of metal additive manufacturing.

2.4 Chapter 4 - Target groups

- In our opinion there are two main target groups:
  - Highly motivated people who are interested in this progressive process and who consider starting their own business in this field.
  - Employees of companies that consider buying a metal 3D printer.
- The program could be interesting also for students and other groups but the factor of the price for the program can be quite limiting.
- The program would be done in cooperation with Brno University of Technology, as StrojLab is part of BUT. BUT could also help with to promotion of the education program.

2.5 Chapter 5 - Requirements for implementation of digital fabrication into credit system

- Based on the research carried out in the problem of implementation of digital fabrication into ECTS credit system, following conclusions were made:
  - Course can be implemented as few days' lasting in lifelong learning at Brno University of Technology. This option would be paid and accessible for anyone. Unfortunately, there are only limited options how to award this course by ECTS credits. As the EUA Bologna Handbook: Making Bologna Work states, "Degree awarding institution must always evaluate the work done or competences obtained before this can be included in the institution's own degree program."

  - Course can be implemented as one semester subject in English language and can be attended also by Erasmus student. Then it depends on the sending institution if it recognizes the credits for this subject in its own degree program. This option is not paid. Proper degree program, where the course would fit with its content, has to be found in the institution where the course would be taught (BUT).
  - Course taken as a one semester already taught subject Additive Technology in Czech language. This option is not paid.
- Two general conclusions were made: 1) It depends more on the sending institution if the credits for the attended course/subject are recognized as valid for the learner degree program than on the institution where the course was taught. 2) Credits are not an entity in themselves, but always describe work completed which is part of a curriculum or a stand-alone unit. Credits are awarded in the context of the program of studies (Making Bologna Work).

2.6 Chapter 6 - Course content

Definition of learning outcomes:

Participants of the education program should after completing the program:

- know what are the technologies of metal additive manufacturing, where they are used what are the benefits of each technology and what are the drawbacks.
- understand the process of selective laser melting (SLM), influence of the main process parameters, strategies used in the SLM technology and typical malfunctions
- be able to prepare the data for the manufacturing process, orient the part in the building chamber, prepare the supports for the part, set the process parameters, prepare the material used for the manufacturing, prepare the machine, remove the model from the platform, remove the supports and treat the surface of the part.

Mode of delivery:

Face-to-face delivery based on lectures and seminars/laboratories

Prerequisites and co-requisites (if applicable):

Prerequisite is knowledge of common CAD systems, such as CATIA, Creo Parametric, Rhinoceros, Inventor.

Course content

Basic course:

- Introduction

  - Selective laser melting
  - Electron beam melting
  - LENS Metal Additive Manufacturing Technology
- SLM Process Parameters
  - Laser parameters (laser speed, laser power)
  - Process map
  - 3D print strategy
  - Input powder parameters
- Preparation of data – Basic pre-processing
  - Data transfers
  - Solutions for polygonal network errors

Advanced course:

- Production preparation
  - Preparation of powder materials
  - Humidity
  - Machine preparation
  - Sighting equipment
- Sample Construction
- Production Validation – Microscopy
  - Identification of material violations
  - Identification of the influence of process parameters
  - Typical malfunctions
  - Examples of production failures
- Production
  - Orientation in the chamber
  - Supports
  - Process parameters
- Post-processing
  - Removing of model
  - 3D digitization
  - Removing of supports
  - Surface treatment
- Inspection
  - 3D optical digitization
  - Evaluation of geometry deviations
  - Surface structure

Recommended or required reading and other learning resources/tools

Igor Yadroitsev. Selective laser melting: Direct manufacturing of 3D-objects by selective laser melting of metal powders. 2009, LAP LAMBERT Academic Publishing. ISBN: 978-3-8383-1794-6.

Planned learning activities and teaching methods

There is a plan for lectures to give the participants the theoretical knowledge. The seminars will be focused on practical knowledge of software tools. Laboratory classes are focused on practical tests, measurements and evaluations.

Assessment methods and criteria

To complete the program, participants will be demanded to finish a project and hand in the final report in digital form. They will also need to complete the test of theoretical knowledge.

Language of instruction

Czech/English

2.7 Chapter 7 - Financial resources

The course expenses (machine time, lecturer wage) will be financed by the participants in the form of a fee for the course (in the case of a course in lifetime learning). There will be no extra financial resources needed for implementation of the course as the course has been already prepared and tested during the Pilot action of FabLabNet.