Enhancing EU Employability
by Adult Training in 3D Printing

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3D Printing Case Studies for Adult Education

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Revision History

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1. Background

With the European Union actively engaging in a number of activities and events to help Europe to Re-Industrialise (http://www.reineu2016.eu/), there is an urgent need to help European adults to catch up with competences and skills in a number of new technologies that are now readily available.

Also, of relevance is the fact it is well known that Europe is at the early stages of the 4th Industrial Revolution (or Industry 4.0) which aims at exploiting digital technologies for improved productivity and growth levels. One such technology on which Industry 4.0 greatly depends is 3D-Printing, a technology that is creating new jobs and opportunities. At the same time, according to the EU's Digital Skills and Jobs Coalition (2016), around 45% of EU citizens are digitally illiterate! As digitisation penetrates more aspects of our daily life from tasks at home, to tasks at work, the demand on EU adults to be skilled in digital literacy is thus daily increasing. In Dec 2016, the EC issued a recommendation on 'Upskilling Pathways, New Opportunities for Adults' precisely aimed at addressing such problems. Thus, one such upskilling required is that related to making EU adults competent in 3D-P technology.

The range of possibilities which 3D printing provides is almost limitless. However, one area where 3D printing has yet to make a difference despite the potential of fulfilling many needs is within the educational systems. The 3D-HELP project aims to help Adult Education providers to incorporate 3D printing as part of the curriculum.

The present document provides real life examples of how 3D printing can be successfully thought to adults in a number of sectors. The goal is to acquire essential information for the following steps in the project and, also, to provide inspiration for anybody interested in using 3D printing in Adult Education.

2. Case-studies related to the use of 3D printing in Adult Education

This section provides a selection of the most relevant case-studies identified by the partnership relative to the use of 3D printing in Adult Education. These are taken from different areas: cultural education, language and arts, entrepreneurship, social sciences and STEM (Science, Technology, Engineering and Math). The partnership decided on a common structure for the case studies, in order to efficiently evaluate the most significant features. The main features considered are as follows:

- Type of training
- Aim of the training activity
- Learning outcome
- Target Groups
- Contribution of the training activity to Adult Education
- Hardware/software required for class implementation
- Course prerequisite (if relevant)
- Number of hours needed for training

A short description of the training activity, including URL, course provider, cost, etc. is also given.

Figure 1: Case study area

Case study no.:	*1*
Case Study Title:	3D Printing for the preservation of cultural heritage
Type of training	x Classroom □ Online □ Webinar x Workplace □ Blended Learning □ Other. Please specify: _____
Aim:	To improve the experience, accessibility and value of cultural heritage through visual-tactual models
Learning outcome:	• To acquire knowledge on different aspects of culture through three-dimensional (3D) printed models • To understand learn how 3D representations of objects are acquired and how 3D printing can be used in both replication and restoration of artefacts. • To appreciate the benefits that 3D printing brings to the society, especially to persons with impairments such the visually impaired.
Description:	3D printing in cultural heritage has nowadays been instituted throughout the world. From restoration of statues to creation of three-dimensional visual arts or customised parts, 3D printing is providing a complete appreciation of objects and the technology behind it.
Target Groups:	• Artists, historians, conservators and people working in museums, • Educators that want to transform their way of teaching culture by creating puzzles, objects and other artefacts related to the country's culture. • Adults who are interested in learning about the application of 3D printing in culture.
Contribution to Adult Education:	Through the use and application of 3D Printing technology, people can gain a multisensorial experience of culture, how to use 3DP to restore and preserve cultural heritage and how to digital representation of objects can be easily achieved.
Hardware/software required for class implementation	• 3D printers available • 3D scanners • Learners are recommended to bring their own laptop and mouse to the class
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.
Number of hours:	Varies – depends on the course content.
URL:	https://link.springer.com/chapter/10.1007/978-3-662-44630-0_9 https://www.researchgate.net/publication/283489307_Use_of_3D_Printing_by_Museums_Educational_Exhibits_Artifact_Education_and_Artifact_Restoration http://www.digitalmeetsculture.net/article/3d-printing-applied-to-cultural-heritage/

Figure 2: 3D printed representation of the Goddess of Fertility (a.k.a. The Fat Lady) found in Neolithic temples of Malta

Case study no.:	*2*
Case Study Title:	3D Printing for creation and/or repairing musical instruments
Type of training	x Classroom x Online □ Webinar □ Workplace □ Blended Learning □ Other. Please specify: _____
Aim:	To equip adult students with 3D printing skills, fundamentals in the science of sound in musical instruments
Learning outcome:	• To link the theory of music / sounds in relation to the different materials that can be used for 3D printing. • To acquire knowledge on how to create/modify musical instrument components through 3D printing.
Description:	Thingiverse.com offers various courses on the use of 3D printing for education. There are various musical instrument families, and most of them can be 3D printed entirely or combined with other materials such as nylon strings (for guitars) in order to produce different sounds. The science of sounds is simple and complex at the same time. Principles in the design of an instrument (e.g. air flow efficiency, surface area, hollowness, etc.), the material used (plastic, wood, metal), the way the instrument is held, and other factors collectively contribute to the generation of different sounds. Thus, through 3D printing one can recreate traditional musical instruments along with a chance of creating new ones. Other instruments can have. At the end of this course, adults shall acquire deeper knowledge about a particular instrument as well as apply 3D printing to create/repair such as device.
Target Groups:	• adults interested in acquiring deeper knowledge in music or want to learn an instrument • people that want to learn how to recreate traditional and/or modern musical instrument, • technical people that want to explore how the sound of a musical instrument can be altered.
Contribution to Adult Education:	Through this course, adult learners can acquire skills and knowledge in theory of sound and design of instruments. Additionally, opting to creating 3D models from the beginning will allow individuals to gain/improve 3D modelling skills. Furthermore, such knowledge can aid individuals in repairing musical instruments or other objects.
Hardware/software required for class implementation	• 3D printers available • Blueprints of musical instruments • Learners are recommended to bring their own laptop to access to a computer with design software
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.
Number of hours:	Varies

URL:	https://www.thingiverse.com/thing:1735985/#files https://www.thingiverse.com/thing:1733645 https://www.thingiverse.com/thing:662115

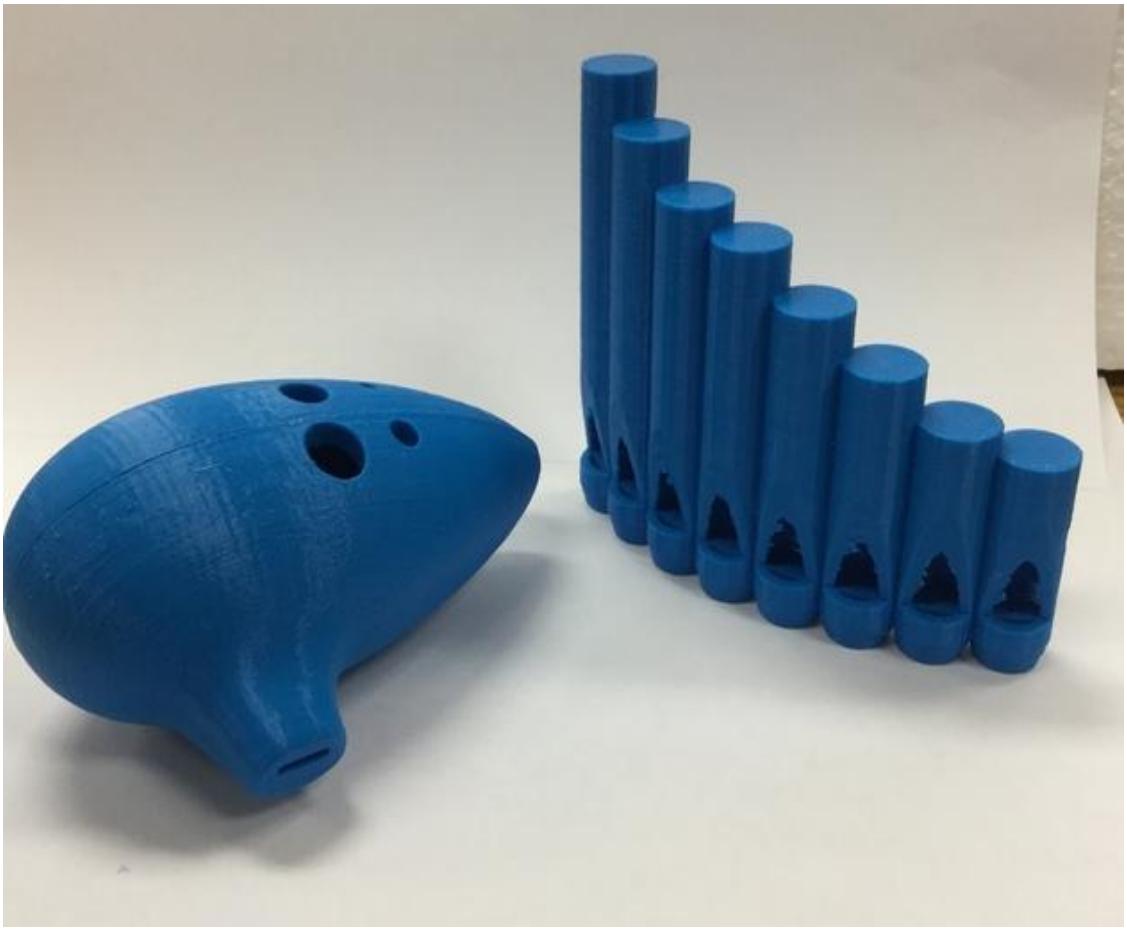

Figure 3: Making Music by: Maria Marsicano

Case study no.:	*3*
Case Study Title:	3D printing for learning Egyptian hieroglyphic writing systems
Type of training	□ Classroom x Online □ Webinar □ Workplace □ Blended Learning □ Other. Please specify: _____
Aim:	To allow learners gain knowledge on ancient languages and the phonetics through 3D printing
Learning outcome:	• To learn different writing systems • To acquire knowledge of how to translate English words into hieroglyphics and possibly be able to exploit 3D printing to conserve hieroglyphics • To learn about different countries' history, language and arts.
Description:	Thingiverse.com offers various courses on the use of 3D printing for education. Egyptian Hieroglyphics is one course aimed for children and teachers to equip them with basic hieroglyphic, cultural and language skills through the use of 3D printed hieroglyphics. However, the content can be improved to make it adult appropriate or even teach how new hieroglyphics can be created through 3D printing. At the end of this course, the learners acquire the skills need to translate words to their mother tongue or any other language.
Target Groups:	• tourists interested to visit a country that has ancient a writing system, • artists who want to understand the visual arts with respect to history and culture • adults who want to gain further knowledge in foreign languages, world history and anthropology, e.g. tour guides being able to interpret historical glyphs; (tattoo) artists drawing hieroglyphics with meaning; people that want to sell cartouches or name plates
Contribution to Adult Education:	Through this course, adult learners acquire language and cultural knowledge, and how different glyphs sound. These, in turn, could be applied throughout their careers.
Hardware/software required for class implementation	• 3D printers available • Learners are recommended to bring their own laptop to the class if new 3D hieroglyphics will be created
Course prerequisite (if relevant)	• Computer literate. No previous CAD knowledge is required.
Number of hours:	Varies – depending on the content
URL:	https://www.thingiverse.com/thing:1699935 – Egyptian writing system

Figure 4: *Egyptian Hieroglyphics - Making a Cartouche by Dionicio Gonzalez*

Case study no.:	*4*
Case Study Title:	3D Printing in fashion: shaping tomorrow's human culture
Type of training	x Classroom □ Online □ Webinar □ Workplace □ Blended Learning □ Other. Please specify: _____
Aim:	To present learners how 3D printing is revolutionising the industry of fashion and the culture behind it by learning about 3D printing and its technology.
Learning outcome:	• To acquire knowledge on how to apply 3D printing to producing creative objects, in particular carnival items; • To train students in using 3D modelling software • To acquire knowledge on basic properties of different materials suitable for printing fashion accessories (e.g. carnival items); • To understand the limitations and possibilities of 3D printing and possibly use it to create prototypes and samples.
Description:	Clothing is one of the major identities of a country's culture. In all human cultures, people dress the body in different ways, being clothing, garments, tattoos or other forms of body painting in order to embellish the body. Within the cultural domain, the need to dress is called 'fashion'. 3D printing in fashion has been used to create customised jewellery and headpieces with intricate details, panel trammels (i.e., accessories to which traditional fabrics can be attached and complete dresses) shoes and much more.
Target Groups:	• Fashion (dress, jewellery, etc.) designers in various industries (e.g. costume design in films) that want to prototype ideas or print entire collections. • Historians that are studying different civilisations and want to reproduce/restore models for exhibitions. • Laypeople who want to create customized pieces of jewellery (and dresses)
Contribution to Adult Education:	Through this course, adult learners can acquire insight how 3D printing is revolutionising the human culture with respect to fashion and to provide the tools necessary for aspiring learners to utilise such technology in order to continue develop professionally. An American fashion designer, Travis Fitch, said that "you can't take 3D printing out of the equation. Most of what we were trying to do was geared towards creating geometry that you can only make in a certain way". As the fashion world is continuously developing, understanding 3D printing and the process of creating objects through an additive manufacturing process will equip designers with the necessary tools to compete in this industry.
Hardware/software required for class implementation	• 3D printers available • Learners are recommended to bring their own laptop and designs of fashion-related items.
Course prerequisite (if relevant)	• Computer literate. • Previous CAD knowledge would be beneficial but not a necessity.
Number of hours:	Depending on content.

URL:	https://link.springer.com/article/10.1186%2Fs40691-017-0111-3 https://researchportal.hw.ac.uk/en/publications/3d-printing-for-garments-production-an-exploratory-study https://www.thingiverse.com/thing:1622800 https://ultimaker.com/en/explore/where-is-3d-printing-used/fashion

Figure 5: Carnival Costumes in Malta

Figure 6: Maltese Carnival float

Case study no.:	5
Case Study Title:	3D Printing and Biofabrication
Type of training	x Classroom □ Online □ Webinar □ Workplace □ Blended Learning □ Other. Please specify: _____
Aim:	To provide insight in the opportunities of additive manufacturing technologies and 3D printing in biomedical applications. In addition, it will also provide insight in the specific challenges encountered when translating 3D printing to biofabrication, such as the development of specific bio-inks and the required control over processing conditions. Finally, it will provide state-of-the-art examples of how currently biofabrication is translated from bench towards the bedside.
Learning outcome:	• To acquire basic knowledge in 3D printing • To acquire basic knowledge in 3D design software • To understand the specific challenges encountered when translating 3D printing to biofabrication
Description:	In July 2018 the fifth 3D Printing & Biofabrication summer course will be organized in Utrecht. The course will provide the basics of 3D printing, including a hands-on Ultimaker workshop in a FabLab and introduction to 3D design software. In addition, it will contain lectures by international specialist on the specific challenges encountered when translating 3D printing to biofabrication. Lectures and workshops from companies involved in the field of medical 3D printing are also part of the program. Specific topics include the development of bio-inks, development and application of 3D in vitro models and the required control over processing conditions. Finally, it will provide state-of-the-art examples of how currently biofabrication is translated from bench towards the bedside. We encourage you to take this course in combination with the Regenerative Medicine summer school course.
Target Groups:	• Students of Utrecht University - Faculty of Medicine
Contribution to Adult Education:	Through this course, students of Utrecht University can acquire some basic skills and knowledge in 3D printing, 3D design software and can get insight in the specific challenges encountered when translating 3D printing to biofabrication
Hardware/software required for class implementation	• 3D printers
Course prerequisite (if relevant)	• The course is Advanced Master, so some skills are required, however, it was not specified which particularly
Number of hours:	25-30
URL:	https://www.utrechtsummerschool.nl/courses/life-sciences/3d-printing-and-biofabrication

Case study no.:	*6*
Case Study Title:	3D Printing workshop: development, application and its contribution to local economy
Type of training	x Classroom ☐ Online ☐ Webinar ☐ Workplace ☐ Blended Learning ☐ Other. Please specify: _____
Aim:	To drive lateral thinking and radical approaches to address research and 3D printing innovation challenges and to develop research and innovation projects which contributed regional economy development, especially firstly in the Solent Area and then to the UK scope.
Learning outcome:	• To understand the digital opportunities related to 3D printing • To understand the 3D printing potential contribution to local/national economy • To acquire knowledge on how to develop research and innovation projects contributing to the regional economy grow
Description:	Full day workshop organised by Dr Jessie Qun Ren, Senior Lecturer in Marketing, Southampton Solent University, supported by HEIF funding where various speakers contributed. It provided an opportunity to explore and discuss the digital opportunities, especially the development and application of 3D printing technology and its potential contribution to local/national economy. It was a valuable opportunity to explore, extend and strengthen the network.
Target Groups:	• Anyone interested in 3D printing development and application in 21st century
Contribution to Adult Education:	Through this course, adult learners could explore and discuss the digital opportunities, the development and application of 3D printing technology and its potential contribution to local/national economy with various speakers, including Professor Richard Hua-Li, Founder of China Association for Management of Technology and CAMOT Innovation Academy Cambridge, and Former President of Sias International University, China.
Cost	• The workshop was free
Course prerequisite (if relevant)	• No previous CAD knowledge was required
Number of hours:	6.5
URL:	http://www.bcs.org/content/conWebDoc/56208

Case study no.:	*7*
Case Study Title:	3D imaging: Surface scanning, 3D printing and hands on Amira training
Type of training	x Classroom ☐ Online ☐ Webinar ☐ Workplace ☐ Blended Learning ☐ Other. Please specify: _____
Aim:	The objective of the training was to provide hands on training on a 3D multifaceted software platform (Amira, Visage Imaging) for visualizing, manipulating, and understanding 3D reconstructions of bio-medical data and/or other sets of data. The second day of the training was about the use of the 3D surface scanner (3D3Solutions), which is available in Archaeology, and the relevant software Flexscan 3.0.
Learning outcome:	• To acquire knowledge on the 3D multifaceted software platform (Amira, Visage Imaging) for visualizing, manipulating, and understanding 3D reconstructions of bio-medical data and/or other sets of data • To learn how to use of the 3D surface scanner (3D3Solutions) and the relevant software Flexscan 3.0 • To acquire knowledge on 3D printing
Description:	EUFA (Edinburgh Unit for Forensic Anthropology) has acquired a simple 3D printer for small objects (Printrbot Simple) which can be used for replicas of bones and artefacts which can be of particular interest in Forensic Anthropology, Osteoarchaeology and Archaeology. An introduction to 3D printing and possible applications were given by Diego Zamora, PhD candidate at the College of Arts. The second training included a general description of the 3D surface scanner (technical characteristics of the scanner, scanning processes, the software etc.) and the actual scanning of several different objects such as: 1. Faces 2. Dry bones (e.g. skulls) 3. Ceramic artefacts 4. Metallic artefacts and/or jewellery
Target Groups:	• Students and adults interested in 3D printing
Contribution to Adult Education:	Through this course, adult learners acquired some basic skills in 3D multifaceted software platform (Amira, Visage Imaging), in the use of the 3D surface scanner (3D3Solutions), which is available in Archaeology, and the relevant software Flexscan 3.0. Participants were provided a general description of the 3D surface scanner (technical characteristics of the scanner, scanning processes, the software etc.) and the actual scanning of several different objects.
Hardware/software required for class implementation	• 3D printers available

Course prerequisite (if relevant)	• Computer literate
Number of hours:	10
Number of participants:	20 participants for each training day
URL:	http://edinburgh-unit-fa.wixsite.com/eufa/3d-imaging-workshop

Case study no.:	8
Case Study Title:	Introduction to Computer Aided Design (CAD) and 3D Printing
Type of training	x Classroom □Online □Webinar □Workplace □Blended Learning □Other. Please specify: _____
Aim:	To equip adult learners with the skills needed to create 3D models with CAD software and to 3D print them
Learning outcome:	• To acquire knowledge on computer aided design (CAD) concepts • To understand how to create 3D models for 3D printing • To acquire knowledge on 3D printing
Description:	The MVLA Adult School offers an introductory course on Computer Aided Design and 3D Printing. At the end of this course, the learners acquire the skills need to design with CAD software and to 3D print their designs.
Target Groups:	• parents or caregivers interested to design engaging projects for and with children, • engineers who want to prototype • technically curious individual interested
Contribution to Adult Education:	Through this course, adult learners can acquire some basic skills and knowledge in 3D modelling and 3D printing. These, in turn, could be further improved and used to start a business, to get a job, to develop hobby activities, etc.
Hardware/software required for class implementation	• 3D printers available • Learners are recommended to bring their own laptop and mouse to the class
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.
Number of hours:	50
URL:	http://www.mvla.net/view/35829.pdf, page 12

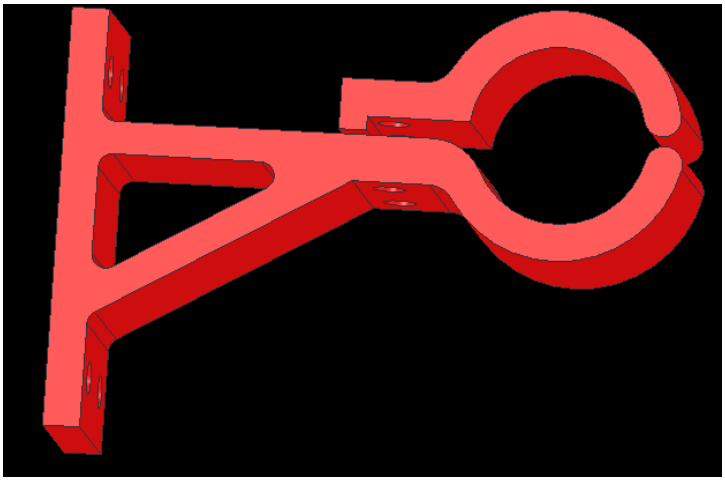

Figure 7: 3D model created using CAD

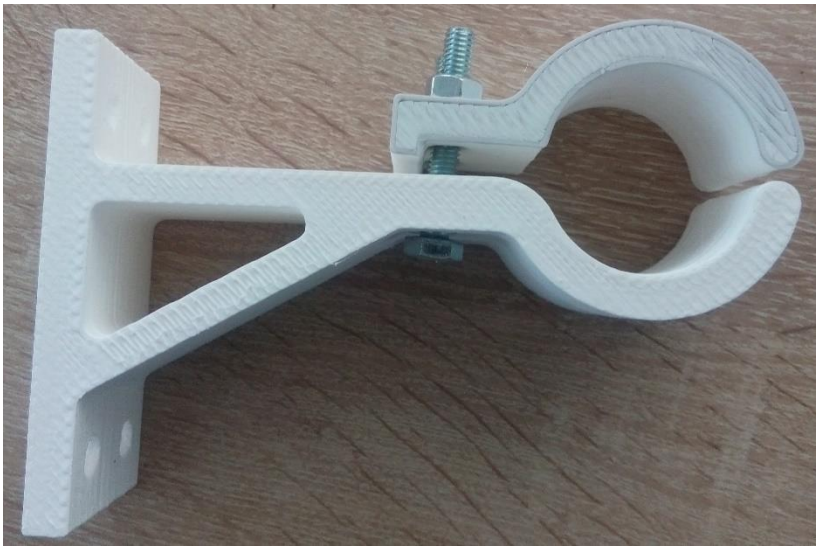

Figure 8: 3D printed model

Case study no.:	9
Case Study Title:	3D Printing classes for adults at Museum of Design Atlanta
Type of training	x Classroom □Online □Webinar □Workplace □Blended Learning □ Other. Please specify: _____
Aim:	To provide an introduction to 3D designing for adult learners.
Learning outcome:	• To acquire knowledge on 3D printing • To understand how 3D printing is changing design processes and its impact • To acquire knowledge on the fundamentals of a basic CAD software • To acquire knowledge on how to prepare CAD files for 3D printing
Description:	The Museum of Design Atlanta organizes classes for adults, to provide an introduction with 3D printing. An instructor guides participants through the process of creating a 3D printable object using a CAD software and preparing the file to be 3D printed. Most of the class is spent designing objects for print. These are printed after the learners leave the class session and can be picked-up later.
Target Groups:	• Adults (16+)
Contribution to Adult Education:	Through this course, adult learners can acquire some basic skills and knowledge in 3D design and 3D printing. This way, they can take advantage of a wide range of opportunities provided by the 3D printing technology.
Hardware/software required for class implementation	• 3D printers available
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.
Number of hours:	1.5
URL:	http://www.museumofdesign.org/hands-on-design/

Figure 9: Object created by combining CAD design, 3D printing and painting

Case study no.:	10
Case Study Title:	Designing jewellery for 3D Printing
Type of training	□Classroom x Online □Webinar □ Workplace □Blended Learning □ Other. Please specify: _____
Aim:	To provide knowledge regarding 3D printed jewellery creation.
Learning outcome:	• To acquire knowledge on modelling jewellery for 3D printing using ZBrush and Maya • To understand the workflow required to create a model intended to be 3D-printed in wax and cast in silver • To learn how to check quality of the model to be 3D printed • To learn how to prepare CAD files for 3D printing
Description:	Helen Duckworth, Senior modeller, offers an online course dedicated to the adults wishing to design their own jewellery and to 3D print them. The trainees learn how to use Autodesk Maya, ZBrush and Photoshop to create their models, to check their quality and to set them for 3D printing
Target Groups:	• Anyone interested in creating jewellery by 3D printing
Contribution to Adult Education:	Through this course, adult learners can acquire knowledge in 3D design using Maya and ZBrush and how to set the models for 3D printing. With these new skills, adults can create jewellery for themselves or for selling and, also, can start a business.
Hardware/software required for class implementation	• Software: Autodesk Maya, ZBrush and Photoshop
Course prerequisite (if relevant)	• Computer literate.
Number of hours:	1.5
URL:	https://www.pluralsight.com/courses/designing-jewelry-3d-printing-zbrush-maya-2152ing

Figure 10: 3D printed bracelet

Case study no.:	*11*
Case Study Title:	3D Printing for entrepreneurs
Type of training	□Classroom x Online □ Webinar □ Workplace □Blended Learning □ Other. Please specify: _____
Aim:	This course will teach you about what 3D printing is and how to make money off of it.
Learning outcome:	• To acquire knowledge on 3D printing • To understand 3D printing's historical perspective • To learn how to earn money using 3D printing
Description:	In this course learners will learn by example: 3D modelling (virtual computer design), how to print objects and sell them. This training course consists of 11 videos. Curriculum for This Course is: 1. Introduction (01:38 min. duration) 2. What is 3D Printing? (05:05 min. duration) 3. History of manufacturing (06:42 min. duration) 4. Where is 3D printing today? (03:52 min. duration) 5. What is 3D printing useful for? (05:01 min. duration) 6. This is a great opportunity (05:46 min. duration) 7. Where do you start? (02:19min. duration) 8. How to get better at 3D printing? (04:36 min. duration) 9. How to make money off of 3D printing? (05:06 min. duration) 10. Making a small chess piece in the 3D modelling software Blender (05:11 min. duration) 11. Exporting the Blender file to STL so that you can 3D print the object (2:30 min. duration)
Target Groups:	• This is a course for people who know nothing about 3D printing - complete beginners
Contribution to Adult Education:	By completing this course, adult learners can acquire some basic skills and knowledge in 3D printing. After completing the course learners could make money as a side job, start a business, to start a new career. After completing this course learners get Certificate of Completion.
Hardware/software required for class implementation	• Blender (open source software for 3D creation https://www.blender.org/)
Course prerequisite (if relevant)	• Complete beginners
Number of hours:	1 hour
Provider of the course, country	This course is being delivered by Mammoth Interactive (Canada) is a company that was formed in 2008 by John Bura.

Cost	14,99 €
Year of production	2014
URL:	https://www.udemy.com/3d-printing-for-entrepreneurs/

Figure 11: 3D Printers

Case study no.:	*12*
Case Study Title:	How to become a 3D Printing entrepreneur
Type of training	☐ Classroom ☐ Online ☐ Webinar ☐ Workplace ☐ Blended Learning ☒ Other. Please specify: an e-book
Aim:	To equip adult learners with the knowledge of the business practices specific to the industry and to learn how to create a successful business using 3D printing technology.
Learning outcome:	• To acquire knowledge on the history, technology as well as on several ways 3D printing is being used today • To understand how to become a 3D designer and how to be self-employed • To learn what is important to know about a 3D printer • To learn how to earn money in 3D printing
Description:	An e-book "How to Become a 3D printing Entrepreneur" by Yoni Bitstock takes learner on a journey from a 3D printer novice to becoming an expert in the field. The book is broken down into 5 sections. In the introduction, there are a review of the history and a quick explanation of the technology as well as listing several ways 3D printing is being used today. The second chapter is for 3D designers and those interested in learning how to become one. It covers the different software choices, the expected salaries, places to sell created designs, and the opportunities for freelancing. The third chapter focuses on individuals who have or who are looking to purchase a 3D printer. The section covers the different models, how to lease out the printer for extra money. The fourth section presents many of the other fields where learner can earn money in 3D printing including: materials, spare parts, scanning, software, teaching, and much more. After the conclusion, there is a list of over 50 resources plus words of wisdom from other 3D printing entrepreneurs. They are world renown artists, CEOs of start-ups and of well established companies, successful freelancers, and many others inspiring entrepreneurs. E-book is available in 3 different formats: PDF, EPUB, and MOBI.
Target Groups:	• everyone who is interesting how to become a 3D printing entrepreneur
Contribution to Adult Education:	Through this e-book, adult learners can acquire some basic knowledge in 3D printing entrepreneurship, have an inspiration to start own business or to get a job. This e-book is for self-direct learning, but it could be used for the reversed learning as well: the learners read this e-book at home and later have the discussion in the class.
Hardware/software required for class implementation	• No special requirement for class implementation. The adult educator could use the study circle methods to facilitate discussion on knowledge obtained via self-learning in order to deepen learners' understanding how to become a 3D designer and how to become self-employed.

Course prerequisite (if relevant)	• Computer literate (to download the e-book and read it)
Number of hours:	Up to learner's capacities on own speed (18 pages)
Provider of the course, country:	Author of e-book Yoni Binstock, USA
Cost:	Free
Year of production	2014
URL:	https://books.noisetrade.com/yonibinstock/how-to-become-a-3d-printing

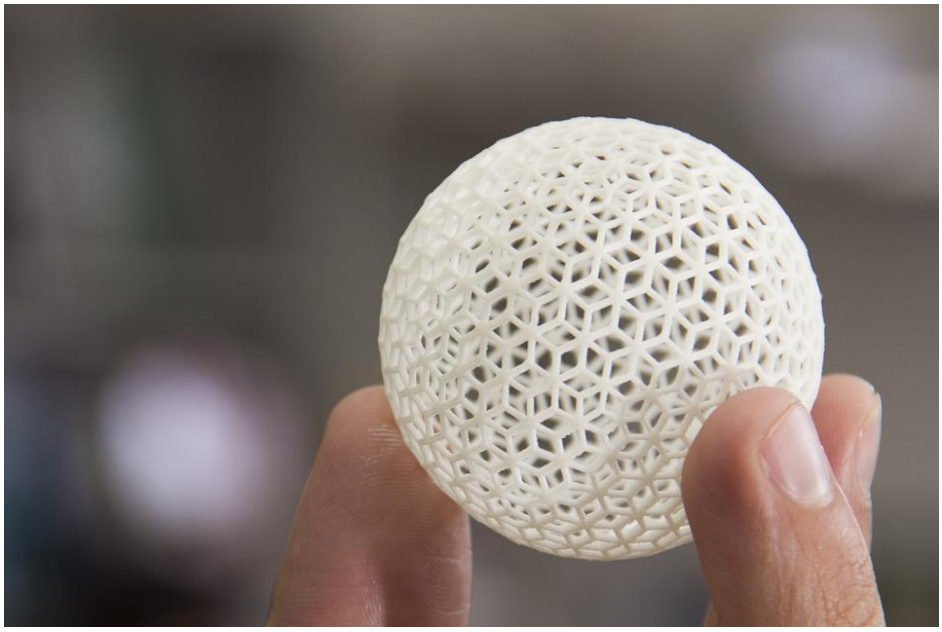

Figure 12: 3D Printing

Case study no.:	*13*
Case Study Title:	The 3D Printing revolution
Type of training	☐ Classroom ☒ Online ☐ Webinar ☐ Workplace ☐ Blended Learning ☐ Other. Please specify:
Aim:	To equip adult learners with the knowledge on how 3D printers work, the type of things they can make, and how learners can use this technology as an entrepreneur, business person, and consumer.
Learning outcome:	Upon successful completion of this course, learners will be able to: • To obtain a rich understanding of 3D printing, including how it works and what you can make • To understand the revolutionary advantages of 3D printing and the exciting future of this technology • To learn about real-world examples and interviews by experts in the field • To see 3D printing in action • To learn how to obtain free digital designs that can be turn into 3D printed objects
Description:	This course demonstrates how 3D printers work, show what people make with them, and examine the 3D printing ecosystem. It also explores the future of 3D printing and discusses how this technology will revolutionize our world. The course materials include informative video lectures, on-location interviews with a variety of 3D printing experts and engaging hands-on exercises. Learners who complete this introductory course get a solid understanding of 3D printing and its revolutionary potential and will be able to print and customize 3D designs. In Module 1, learners learn what 3D Printing is, how 3D Printers work, and the types of objects you can make using this technology. In Module 2, learners learn what is special about 3D Printing and how this technology will change the business world and revolutionize our economy. There is a course summary, which provides the learner with the opportunity to share their thoughts about their experience in this course. The course is comprised of the following elements: **Lecture Videos**. In each module the concepts you need to know are presented through a collection of short video lectures. These videos can be streamed for playback. Both videos and the slides that go along with them can be downloaded. **In-Video Questions**. Some lecture videos have questions associated with them to help verify the understanding of the topics. These questions will automatically appear while watching the video if it is streamed through a browser. These questions do not contribute toward the final score in the class. **Practice Quizzes**. Each module includes one practice quiz, intended for the assessment of learners' understanding of the topics. Learner is allowed unlimited attempts at each practice quiz. Each attempt may present a different selection of questions. There is no time limit on how long it takes to complete each attempt at the quiz. These quizzes do not contribute toward the final score in the class.

	Module Quizzes. Each module includes one for-credit quiz. Learner is allowed 3 attempts per every 8 hours at each quiz. There is no time limit on how long it takes to complete each attempt at the quiz. Each attempt may present a different selection of questions. The highest score is used when calculating learner's final score in the class. **Peer Reviewed Assignments**. Each module includes one peer reviewed exercise. Learner can attempt these assignments multiple times. The highest score is used when calculating learner's final score in the class.
Target Groups:	• everyone who is interesting in 3D printing and its revolutionary potential
Contribution to Adult Education:	Through this e-course, adult learners will have a solid understanding of 3D printing and its revolutionary potential and be able to print and customize 3D designs.
Hardware/software required for class implementation	• No special requirement for class implementation.
Course prerequisite (if relevant)	• Computer literate (to access and to learn course)
Number of hours:	2 weeks of study, 3-4 hours/week
Provider of the course, country:	University of Illinois at Urbana-Champaign, USA
Cost:	Free
Year of production	2017
URL:	https://www.class-central.com/mooc/5991/coursera-the-3d-printing-revolution

Figure 13: 3D printed house

Case study no.:	*14*
Case Study Title:	Professional development in Computer Aided Design (CAD) and 3D Printing (STEM)
Type of training	x Classroom □Online □Webinar □Workplace □Blended Learning □ Other. Please specify:
Aim:	To equip adult learners with the skills needed to create 3D models with CAD software and to 3D print them
Learning outcome:	• To acquire knowledge on the concepts of computer aided design (CAD) • To learn how to create 3D models for 3D printing • To acquire knowledge on 3D printing • To acquire knowledge on 3D scanning
Description:	A student, high school student, entrepreneur, or just 3D print interested in 3D printing and 3D modelling technology, can attend "3D Fundamentals and 3D Modeling Fundamentals" training for 30 hours. Training will help you master the basic skills required to create functional three-dimensional models. All attendees will be educated on examples of real-life 3D technology application, and practical teaching will greatly contribute to the 3D printers and 3D scanners in the workshop. The education is held in the highly - equipped IT - technical workshop of the Rijeka Development Agency Porin, and the lecturers are experts and experienced professionals specializing in 3D modelling and 3D printing.
Target Groups:	Education is one of the core program activities of the Agency since its establishment. The current trend is the increase in the needs and interests for all forms of informal and formal education. The education is organised on three levels: **Basic** This level is intended for all beginners. i.e. Everyone who wants to learn or are interested about Computer Aided Design (CAD) and 3D printing but have no previous knowledge about it. **Advanced** According to indicated requirements. i.e. Everyone who wants to upgrade their knowledge to compete better on labour market.

	Specific According to the specific needs of their employers. i.e. Employers seek to modernize the firm by using 3D printer in manufacturing on focused product.
Contribution to Adult Education:	After the education, the trainee is certified 30 hours of completed education, about 3D printing bases and 3D modelling, which guarantees the door to the world of new technologies. After finishing the adult learners can use their knowledge: • to implement 3D printing technology in their company • to enrich their resume and be ahead of the competition • to keep the pace with technological progress
Hardware/software required for class implementation	• 3D printers available • 3D scanners available (highly equipped IT - technical workshop)
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.
Number of hours:	35

Figure 14: Printing process

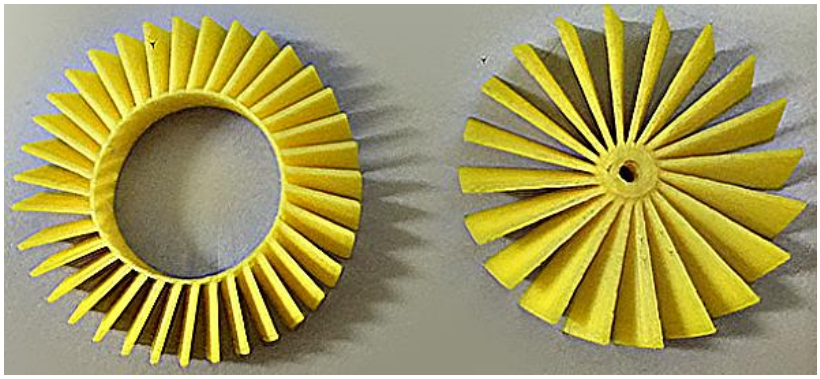

Figure 15: Propeller made by 3D printing

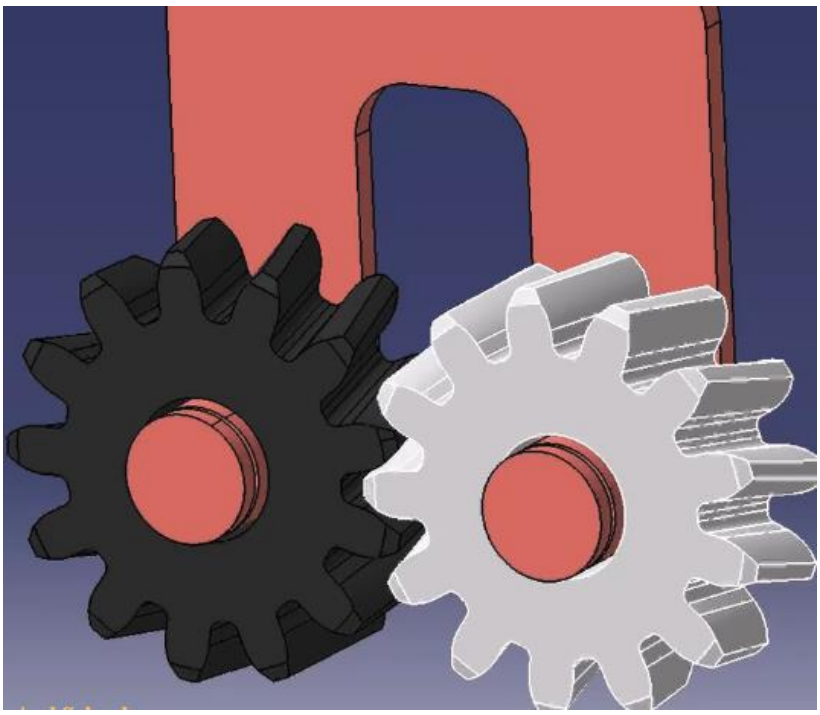

Figure 16: Two 3D helical gears in action – modelling program Catia

Figure 17: Two helical gears in action – made by 3D printing

Case study no.:	*15*
Case Study Title:	Computer Aided Design (CAD) and 3D Printing education in STEM
Type of training	x Classroom □Online □Webinar □Workplace □Blended Learning □ Other. Please specify:
Aim:	To equip adult learners with the skills needed to create 3D models with CAD software and to 3D print them
Learning outcome:	Learning the concepts of computer aided design (CAD) • To learn how to create 3D models for 3D printing • To acquire knowledge on 3D printing
Description:	EDUNOVA school of Informatics and Management – institution for adult education. The practical course is designed for beginners and advanced 3D designers who can enhance their modelling skills Teaching begins with introduction to 3D design and modelling, and then after adopting the model starts an introduction to 3D printing. Participants will use the help of a mentor to create and prepare a 3D print template. During the preparation, an important step is to repair and export 3D finished product files. Participant will use various 3D printing capabilities and techniques. Each student will create their own model on a 3D printer. On this training course participants will be introduced to 3D scanning technology and everything that is already coming to the world of 3D printing. Edunova as a member of the Osijek Software City Initiative participates in raising their students' competences to be more competitive in the labour market.
Target Groups:	• beginners • advanced 3D designers
Contribution to Adult Education:	At the end of the program the participants are able to work independently with 3D technologies in the design of the 3D model. They will be able to independently prepare and create a 3D model on a 3D printer. This is knowledge that will enable new jobs and significantly improve existing business processes.
Hardware/software required for class implementation	• 3D printers available
Course prerequisite (if relevant)	• Computer literate. • No previous CAD knowledge is required.

Number of hours:	130
URL:	• https://www.edunova.hr/informatika/3d-print-dizajner/ • https://www.edunova.hr/wp-content/uploads/2015/03/edu_clean.pdf

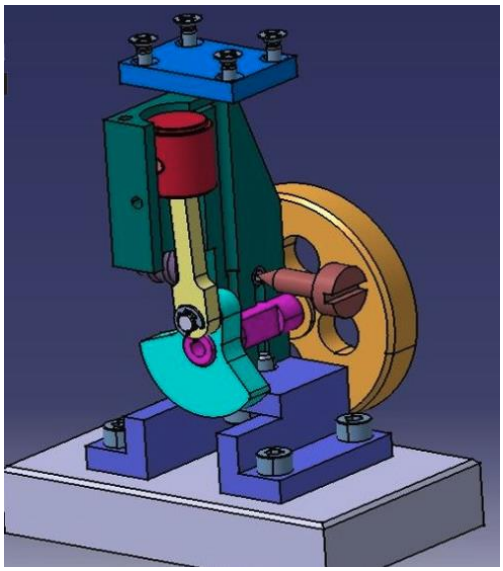

Figure 18: Two-stroke engine – in modelling program Catia

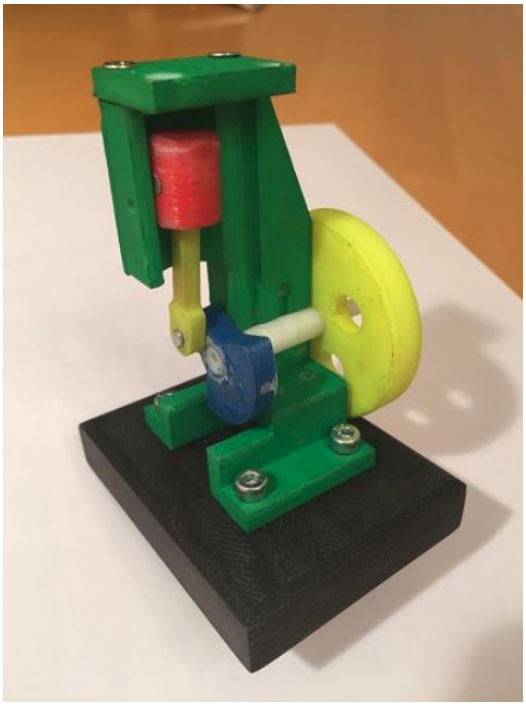

Figure 19: Two stroke engine - parts made by 3D printing

Case study no.:	*16*
Case Study Title:	Development in Computer Aided Design and 3D Printing
Type of training	x Classroom □Online □Webinar □Workplace □Blended Learning □ Other. Please specify:
Aim:	To equip adult learners with the skills needed to create 3D models with CAD software and to 3D print them.
Learning outcome:	• To learn how to create a 3D digital model in the selected application • To acquire knowledge on how to analyse the digital 3D model and determine the errors • To acquire knowledge on the laws and limitations of FDM / FFF technology • To learn how to assess the complexity of a digital 3D model • To learn how to select the optimal parameters for 3D printing • To understand how to differentiate the 3D printing technology • To understand to handle and manage the FFF / FDM 3D printer individually
Description:	HUB385 is home to developers, creators, innovators and entrepreneurs with the goal of promoting innovation, collaboration and knowledge sharing. Training course is divided to modules: Module 1 - Introduction to 3D Academy (3 hours) Module 2 - Basics of 3D modelling (25 hours) Module 3 -3D modelling with the laws and limitations of FDM / FFF additive technology (16 hours) Module 4 - Work with 3D print process management software (16 hours) Module 5 - Setting up and working with a 3D printer (20 hours)
Target Groups:	• People who want to learn about new technologies, complete beginners • People who want to know how can 3D printing be useful and applied in different fields of human development • Engineers who wants to improve their knowledge, focused on specific problems
Contribution to Adult Education:	The workshop is intended for anyone who has always been interested in how 3D technology can be applied and used. The objective of the 3D Academy is to introduce the participants to 3D technology and additive design and to ensure that they acquire basic knowledge and skills in focused fields and wide. They are trying to inspire participants to create using 3D printing, to be entrepreneurs.

Hardware/software required for class implementation	• 3D printers available
Course prerequisite (if relevant)	• No previous CAD knowledge is required.
Number of hours:	80
URL:	• http://www.educentar.net/Program/20502/Akademija-3D-tehnologija/ • https://hub385.com/academy

Figure 20: Model of an airplane interior

Figure 21: Small model of traffic sign and octopus

3. Analysis of Case Studies

In this section, the case-studies previously presented are analysed in order to find out best practices and other useful ideas for the 3D printing (3DP) course. The best-practices for Adult education which emerged across different case studies are discussed below.

3.1 Types of 3DP training in Adult Education

According to our research, the types of 3DP training suitable for Adult Education are very variate, from lecture videos to practical training in classroom, blended learning, e-books, webinars, etc. Depending on the course content, existing facilities and the characteristics of the specific target group, the Adult Education provider can use most of these methods with good chances to deliver a useful 3DP training.

3.2 Learning outcome

Given the broad range of applications suitable for 3D printing, the potential learning outcomes of the related training are many. We have seen in our analysis adults acquiring knowledge in 3D printing technology, 3D modelling software, 3D scanning, materials properties, and various objects production as well as in different aspects of culture, hieroglyphics, material properties, entrepreneurship, social sciences and STEM.

Also, through 3D printing trainings, the adult learners have the opportunity to understand the advantages and the limitations of this technology, the specific challenges related to its use in different applications, how 3D printing is changing design processes and its impact, its historical perspective and exciting future, etc. They learn how to create a 3D model, how to select the optimal parameters and to prepare it for 3D printing, how to assess the complexity and to check its quality, and what is the applied workflow. Also, the adult learners get some hints on how to make money using 3D printing and how to become a 3D printing entrepreneur or self-employed.

Some courses allow learners to see 3D printing in action, to engage them in hands-on exercises, to help them learn about real-world examples

3.3 Target groups

The main target group of the courses presented in this study are adult learners. We found good cases where any adult can take part as well as courses dedicated to a very specific group: artists, historians, designers or technicians interested in a given narrow sector, medical doctors, etc.

Also, quite broad groups are targeted by some courses: teachers/educators, entrepreneurs, engineers, consumers, parents.

3.4 Contribution to Adult Education

Most of the analysed training activities are aimed at giving the adult learners an understanding of 3D printing and help them to acquire related knowledge, skills and abilities.
In addition, some courses are focused on specific sectors and contribute to education of the adult learner in that specific field, e.g. biofabrication, theory of sound, language and arts, etc.
Very often, the 3DP training comes like an extention of the adult learner existing competences. Engineers, designers, archaelogists, medical staff, etc. are adding 3DP skills to their expertise and, consequently, are performing better on their jobs and are able to take new responsibilities and grow their career.

3.5 Hardware and software required for class implementation

This information is considered very important for the Adult Education providers that may want to start offering training in 3DP. For them it's useful to have a good idea about the resources and costs required for such a course.
According to our research, these resources are varying in a wide range, depending on the specific training activity. Most of the cases, one or more 3D printers are needed. Also, computers are required but there is the possibility for learners to use their own laptops. Sometimes, 3D scanners are also required.
Regarding software, this is a must for 3D modelling training. Also, specific software is required for checking and repairing 3D models, to prepare them for 3D printing, for 3D printer management.
There are many options for 3D modelling software, from specialised professional (CAD, 3D art) to free open source. The best option depends on the course's aims, target group budget, etc.

3.6 Course prerequisite

Given the specific of 3DP, the learners must be computer literate. In addition, depending on the course's objectives, some other prerequisite may be established like previous CAD knowledge or specific background in a given sector.

3.7 Number of hours needed for training

This is again a useful information for the Adult Education providers thinking to start offering 3DP training. Depending on the specifics, the 3DP courses duration can vary in a wide range. We found course durations from1 hour to 130 hours!

4. Conclusions

A first conclusion that can be drawn after analysing the case-studies is that 3D printing can be successful used in Adult Education in a really wide range of sectors, from cultural heritage to jewellery design and production, from engineering and technology to entrepreneurship.

Typically, 3D printing is used in conjunction with other technologies needed for creation or preparation of the 3D printing model, post-processing of the 3D printed part, improvement of the final product, etc. Consequently, the 3D printing training is more beneficial when conducted together with other technologies such as Computer aided design, 3D modelling, 3D scanning, STL files processing etc.

A major impact can be obtained if the 3D printing technology is taught like a tool to be used in a given field where the adult learner has already competences. This will help gaining competitiveness, extending the existing capabilities and stimulate innovation and creativity. Examples of such approach are presented in this document from sectors like cultural heritage, music, fashion, biofabrication, forensic anthropology, jewellery, etc.

3D printing offers huge opportunities related to entrepreneurship. In addition, the technology is now readily available, the prices are affordable and new technological advances take place in both equipment and raw materials sectors.
A basic knowledge of 3D printing technology combined with an idea about the opportunities and possibilities related to it can inspire adult learners to find new uses for the technology. This is possible both by implementing 3DP in an existing job and by starting a business.