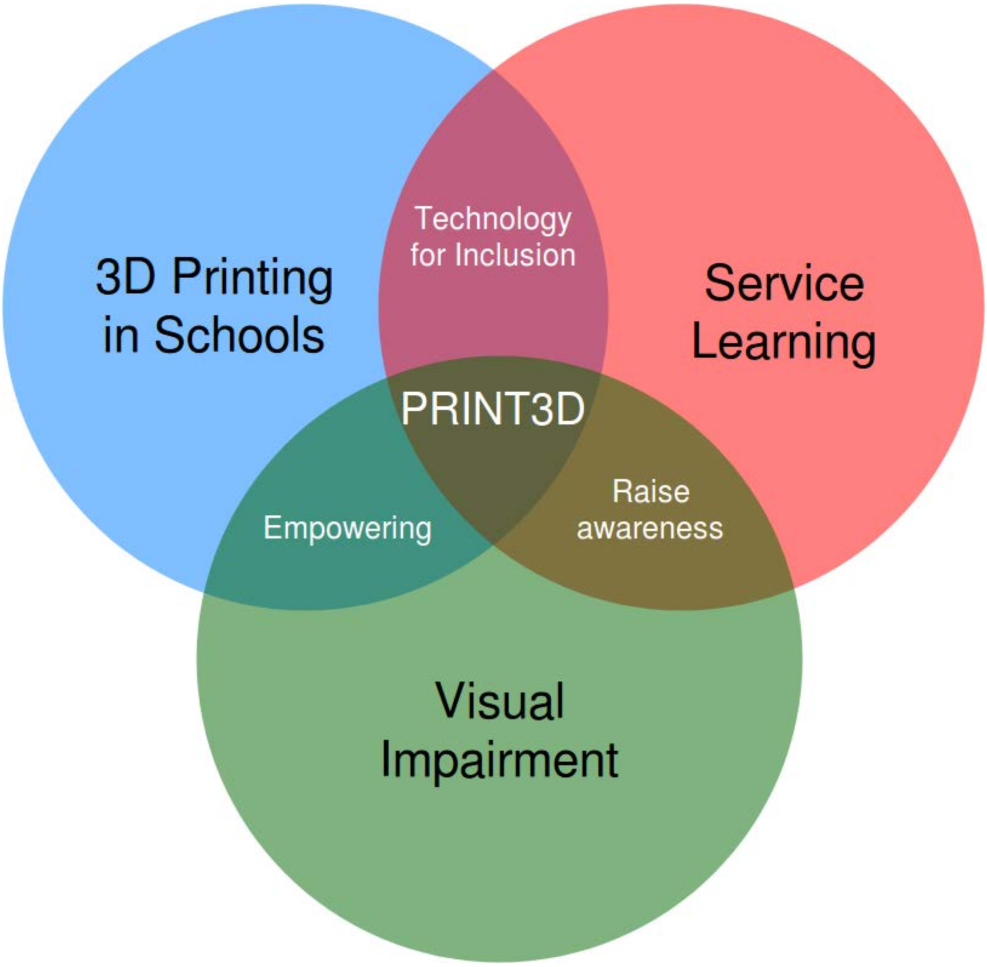
Co-funded by the Erasmus+ Programme of the European Union

Promoting inclusion through educational 3D – printing



Didactic Guidebook for Teachers

Disclaimer

The information provided in the teacher guidebook reflects the opinion of the partnership collaboration and does not imply in any way the opinion of the European Union.

This guidebook is addressed to teachers in order to support them to design practical activities related to service learning aimed at blind and visually impaired people. The guidebook is presented solely for educational purposes and any part or the whole chapter may not be reproduced and used for commercial purpose or sold on the sale market.

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KA" Strategic Partnership for School Education Project
Development of Innovation
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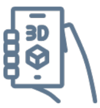
Website page: http://www.erasmusprint3d.eu/

Content

The outputs of the project

Design specific training courses for teachers that include: a) technical and didactic aspects of 3D design and printing; b) knowledge about the service-learning methodology centered on visual impairment.

Develop and edit a didactic unit related to 3D printing connected with the learning service, including a teacher's guide and an associated student mini-textbook.



Train teachers in this regard to implement both ideas in the classroom.

To implement the learning of 3D printing in the classroom, with the aim of generating useful objects for the visually impaired, in particular school plans, as well as plans of outpatient clinics, hospitals, metro stations, urban routes maps, etc.

Involve students with visual impairment in the process of learning competencies in 3D printing, including the design, preparation and/or evaluation of the 3D objects produced.

Make such objects available to the community of people with visual impairment. Depending on the number and quality of the manufactured objects, they can be donated to the "mapped" places (hospitals, museums, etc.).

Frame of the European Project Erasmus+

About 30 million blind and visually impaired people live in the EU countries. Taking into account the different definitions of visual impairments, it can be stated that 1 in 30 people is blind or visually impaired, either from birth, as a result of an accident or due to different diseases. They are trying to find opportunities of inclusion and equal rights. In general, visually impaired people get detailed information about their environment by means of their other senses.

It can be affirmed that education is the most reliable way to success and as a result of a good one, based on one's own efforts, the opportunities for social integration are open. Education is, without a doubt, one of the best ways to combat discrimination. Educationally speaking, one of the skills that the visually impaired should acquire is the improvement of the sense of touch. Until now, the manufacture of three-dimensional objects used for this purpose, has been carried out by various technologies. 3D printing opens up a world of possibilities in this respect, making three dimensional products more accessible, especially for educational purposes.

The main objective of this project is to attend to the inclusion of students with visual impairment. The objective is addressed from several points, including service-learning methodologies that promote awareness of the needs of this group and the educational development of 3D printing skills. The 3D products can facilitate routines and empower the visually impaired students involved in their design, production and evaluation.

It is strongly recommended that the visually impaired attend specific training, but also it should be complemented by inclusive training in conventional schools. Students enrolling in the school for the first time always receive the pertinent documentation that includes, generally: schedules, rules, staff of the centre, facilities plan (blueprint), etc. All these data are usually translated into Braille when a visually impaired student is enrolled. Everything except plans.

The expected impact is obvious. There will be effects, both in awareness-raising about the visual impairment (among the participating students), and in improving the life conditions of the final users of the 3D objects. All the necessary means of diffusion will be used to guarantee its visibility. Likewise, the sustainability of the project is ensured both by the long "useful life" of the objects generated (permanent regarding their designs), as well as by the didactic methodology used. It will be easily replicable in successive years and surely, will leave a mark (in values) in the participating students.

In order to guarantee the success of the project, we have tried to

ensure that the partnership covers the maximum aspects. The partners are: Two governmental and one non-governmental organizations dedicated to the inclusion (education and rehabilitation) of the visually impaired; a company that produces 3D printing equipment; an educational regional institution; several educational centres where visually impaired students are enrolled. In addition, the geographic location of the partners (Greece, Latvia, Spain, and Iceland) ensures enough variety to generate the corresponding synergies, providing very different visions of the project approach, thus ensuring an adequate European dimension.

Partners of the project

- Consellería Educación, Investigación, Cultura y Deporte, Valencia, Spain
- Centre of Education and Rehabilitation for The Blind, Athens, Greece
- Redzi Mani, The Society of Visually Impaired and Blind "Look at me", Latvia
- The National Institute for The Blind, Visually Impaired and Deafblind, Reykjavik, Iceland
- Mundo Reader SL (bq), Madrid, Spain
- I.E.S. Conselleria (public secondary/high school), Valencia, Spain
- I.E.S. Benlliure (state high school), Valencia Spain
- 3rd Gymnasium of Kifissia, Kifissia, Greece
- Ellinoagliki Agogi (primary school), Marousi, Greece
- 4th Dimotiko Sxoleio Pefkis (primary school),Athens, Greece

The main outcome of the project is a guidebook for teachers and a students' mini textbook. The guidebook is designed for teachers in mainstream schools to support their students in participating in different activities which can support people with visual impairment, and is divided into two parts.

The guidebook includes definition, characteristics, classification, types of visual diseases and categories of visual impairment, examples and recommended exercises that can be used with students in the classroom. It also includes technical and practical information, materials, and objects that could be designed and printed in a 3D printer.

Each chapter contains examples of activities, strategies and methodologies to use in practice with students in the classroom, and examples of didactic materials. Ideas for practical exercises designated to be used with students are proposed, and the teacher's guidebook includes several links to interesting or relevant websites and videos. Please check the links before class and if some are not working, try to search the subject and find a working one.

Chapter 1:
Visual impairment and blindness

General overview of the visual system

Vision represents the ability to see. The process is possible due to the complex visual system, which is a part of the central nervous system and connects the eyes with the brain in order to interpret the visual information and give it meaning. The psychological process of visual information is called visual perception. Around 50-60% of information processed by the brain is visual.

The visual system is composed of **three different segments** which contribute to the reception and process of visual information:

Peripheral segment (the receptor) the eye and two parts of the optic nerve. Its role is to capture visual information and forward it to the brain through the optic nerve and visual pathways, for interpretation.

Intermediary segment – sensory pathways – the other two parts of the optic nerve and optic pathways. Its role is to transfer visual information to the visual centre of the brain.

Central segment (brain centre) the occipital cortex in the brain. Its role is to process visual information. It is connected to other centres of the brain which are also responsible for interpretation of visual information such movement, visual scenes, shapes, letters, faces and facial expressions, spatial positions etc.

The visual system has important functions involved in the interpretation of visual information necessary for providing clarity, sharpness, colour, sense of depth, movement and other information about the visual world. All these functions are necessary for higher level interpretation of visual information, so-called visual perception.

Interesting facts:

- We see with our brain and not with our eyes
- The eye functions like a camera. The image is captured by the eye and sent back into the small area called retina. And the fascinating thing is that before the image being interpreted by the brain it is projected upside down into the retina in the back of the eye.
- It is important to have sharp vision and good ability of accommodation in order to see three-dimensionally, to have binocular vision and have a depth perception – to be able to appreciate how far objects are in relation to one's position.
- Children are colour blind at birth
- Around 80% of our memories are produced by what we see
- More than half of the brain is dedicated to the processes of vision
- Eyes can process 36,000 pieces of information in a single hour
- The eye muscles are the most active muscles of the human body

Overview and focus

The focus is on the structure of the visual system - the eye, the visual pathways and the central area of vision in the brain.

The goal is to give students basic information about the visual system and its functions. This will help them understand information in coming chapters regarding how the visual system interprets visual information in case of eye diseases, preparing material, etc.

This could be taught in collaboration with a biology teacher.

Involve students with visual impairment in the process of learning competencies in 3D printing, including the design, preparation and/or evaluation of the "3D objects" produced.

Make such objects available to the community of people with visual impairment. Depending on the number and quality of manufactured objects, they can be donated to the mapped places (hospitals, museums, etc.).

Further information:

- **101 amazing eye facts**
- For ideas of optical activities and testing some optical illusion of the visual system you can visit the site **Optics4 Children**
- National Eye Institute (NEI) on the subpage "NEI for Kids" provides you videos, cool eye tricks, glossary and more. **Here is one page that especially focuses on the biology of the eye**
- **20-20-20 rule:** For people spending a lot of their time in front of a TV or computer screen, it is worth talking about the 20-20-20 rule and instilling exercises as something to do at least once during every computer lesson.

Classification of visual impairment and blindness

Vision impairment is a limitation of one or more functions of the eye (or visual system), and is often defined as the best corrected visual acuity of less than either 20/40 or 20/60. The term blindness is used for complete or nearly complete vision loss. People are not seen as "visually impaired" if the right glasses can correct their vision.

The most common vision impairments affect:

- The sharpness or clarity of vision (visual acuity)
- The normal range of what you can see (visual fields)
- Colour

Visually impaired: a person whose visual acuity is less than 6/18 (30%) with best possible correction (glasses, contact lenses), or if visual field is less than 20 degrees. Seeing 6/18 means that the visually impaired person sees in 6 meters what others see in 18 meters.
Blind: A person whose visual acuity is less than 3/60 (5%), or if visual field is less than 10 degrees.
Legally blind: A person whose visual acuity is less than 6/60 (10%) or visual field is less than 10 degrees. Here is a picture that may show how 50%, 30%, 16% and 10% sight is.

50 %
30 %

16 %
10 %

Presentation of different type of visual impairment

Visually impaired

Visually impaired is a term used to describe people who have some functional vision. It includes people with relatively minor visual difficulties as well as those sometimes described as having low vision.

Their needs vary considerably. Some can read normal print, other need adaptation of text like size, font, or spacing. Aspects that should be taken into consideration in school environment include:

- Environmental conditions may affect the vision, such as light, contrast, seating position etc.
- Comfortable distance for reading from the whiteboard.
- Comfortable size and font of printed text.
- Is the visual field normal or restricted? Reduced peripheral vision or missing areas within the visual field may have impact on the ability to read maps, text etc.
- The time the individual can focus on visual tasks before becoming tired.
- The ability to move independently in known and unknown space.

Common eye diseases

Visual dysfunctions may be the result of different eyes diseases. The most common eye diseases that could affect the visual functions in people, the activity and participation to different kind of activities are as follows:

Injury of the eye: accidents mostly cause injury of the cornea.

Amblyopia: impaired vision in one eye due to the lack of its use. Also known as "lazy eye."

Cataract: clouding of part or entire lens of the eye, preventing light from easily passing through the lens. Symptoms include cloudy or blurry vision, difficulty in seeing in dimly lit areas and bright lights, colours appear faded, double vision etc.

Diabetic retinopathy: diabetes affects the small blood vessels in the retina. When damaged this leads to impairment of vision.

Glaucoma: this condition results due to raised pressure within the eyes. The increased pressure damages the optic nerve.

Age related macular degeneration: a progressive loss of the visual acuity due to damage to the macula that is the most sensitive part of the retina. The center of the visual field appears blurry or opaque. The patient is unable to focus clearly. This mainly occurs in the elderly.

Retinitis Pigmentosa (RP): genetic degenerative disorders of the eye. Symptoms include trouble seeing at night and decreased peripheral vision (side vision), which may eventually lead to "tunnel vision." Onset of symptoms is generally gradual.

Eye Cancer: retinoblastoma is the most common eye cancer in children.

People with visual impairment may experience more than one of the following:

Low visual acuity: difficulty to see images, visual scenes or people sharply. Both distance and near vision can be affected by poor acuity, but not necessarily to the same degree. Some people may be able to see quite small print on a page but be unable to see at a distance, while for others it is difficult to read the text but see at distance.

Central vision loss: difficulty to see with the central vision which affect the way the person sees details. They may be able to move around fairly freely, however, if the rest of their visual field is unaffected. Tasks involving reading, writing and close observation are often difficult for people with central vision loss.

Light sensitivity: difficulty to see clearly in well-lit conditions – sensitivity to light. Some people find bright light painful (photophobia), while others may find it difficult to adjust visually when moving from a bright to a dimly light area or activity.

Patchy vision: difficulty to see visual scenes because of different patches within the visual field which gives a fragmentary image. Complicated visual tasks may become impossible if people can only pick up information in disjointed fragments.

Low contrast sensitivity: difficulty to see an object that does not stand out clearly from its background. For these individuals the lighting and colour scheme of the environment will be especially significant. They may also find the clarity and contrast of print on the page more important than its size.

Eye movement disorders: difficulty to control the eyes for focusing or following objects arises from problems in controlling different muscle functions in the eye. Nystagmus, for example, involves a continuous involuntary movement of the eyes, usually from side to side, which creates significant focusing

Blind

Blind is a term used to describe people who cannot use their vison for reading and writing and rely instead on tactile sense. Some can read text in Braille. Blindness may vary from residual vision to having the sensation of light or being completely blind.

Characteristics:

There are few aspects that should be taken into consideration regarding the blind:

- Ability of tactile sensitivity – exploring the objects, tactile pictures or braille text with fingers
- For someone who lost their vision before the age of four, it may be difficult to remember what objects look like and to build up correct visual representations of e.g. very big objects, like elephant or boat.
- The time the individual can focus on tasks before becoming tired.
- The ability to move independently in known and unknown space.

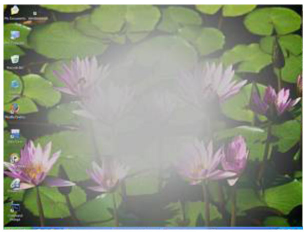
difficulties. Some people may have problems with convergence (the ability to train both eyes on the same object at the same time) while others may find it hard to shift their focus from a near to a far object

Colour vision defects: colour deficiency on its own is not considered to be a vision impairment, but it often accompanies and compounds other visual difficulties. The extent of a colour vision loss varies between individuals, but are likely to involve difficulty in distinguishing detail in pictures, maps and diagrams.

Colour-blindness

The effects of vision impairment on daily life

Eye diseases could affect the individual in different areas of daily life activities from participating in school activity or working time, achieve the tasks at home by preparing their meals or organising their personal belongings to participating at the social life by meeting friends. The severity and impact of eye diseases to a person are related to different factors: the age of eye disease occurrence, the severity of disease, the available services, adaptation and adjustment of environment.



Cataracts - cloudy vision

Cataracts - double vision

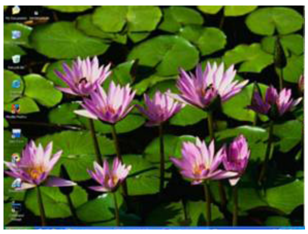
Exercises/Activities

– Explore the environment while visually impaired.

Try walking in small and big spaces – in the classroom, outside classroom in the corridors, walk around the school, using different simulation glasses and/or a blindfold (simulating complete blindness). Students can be divided into groups of two, where one will wear the glasses and the other will guide his/her fellow student to walk safely in the space, give them directions where to walk and protect from possible accidents/incidents. Discuss observation made by students, with the students afterwards in the classroom.

Simple and affordable simulation glasses can be made by adding different materials like plastic, bubble wrap, black paper, or cellophane to disposable safety eyeware/glasses. Glue one or more layers of plastic of cellophane on the lenses of glasses, cut the black paper like the shape of the lenses of glasses and make holes in different part of it in the middle, cut a half of the lens.

Cataracts - yellow vision



Myopia

The sensory and physical environment

The impact of visual impairment on students

Visual impairment may impact active participation in schools, and access to educational material in accordance with the curriculum is an important part for blind and visually impaired students. That is the reason why adaptation of educational material plays an important role in this process.

Speed of working and access to information: most visually impaired students sometimes need longer time to complete a task, especially in the initial stages of development, but this should not be seen as reflecting on their ability and potential.

Glaucoma (RP)

Communication skills: particularly reading and writing. There are different ways to help blind or visually impaired students, such as enlarging text, adapting pictures, using Braille system, tactile graphics, raised maps and diagrams, computers, iPad, to name a few.

Mobility and environmental awareness: lack of incidental visual knowledge means that some students, especially those with more severe visual impairment will need to be taught to navigate their environment independently and safely.

Social interaction: many students with visual impairment find it hard to recognize non-verbal clues, such as body language and facial expression, and may need support in developing social skills.

Self-esteem: there is a risk of students developing low self-esteem, particularly if they experience negative attitudes and stereotyping.

An accessible physical environment can make a difference for visually impaired people in terms of accessibility and independency. Since not all environments can be adapted, blind and visually impaired people should be empowered with other strategies for mobility, orientation, and independently walking. Places and environment that can be safely adapted according to their needs should be adapted and built up in order to enable them to have as much access to the society as possible.

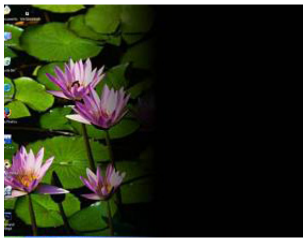
Carrying out environmental assessments and adjustments

Some features should be taken into consideration regarding adaptation of environment and space, especially if students in mainstream schools are participating:

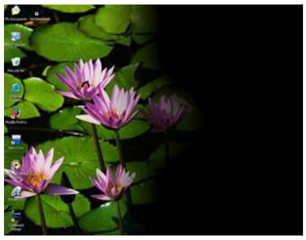
- Signs on doors, entrances, furniture etc.: Clear and visible text, well positioned and easily visible, and braille or symbols for people who use tactile sensitivity for reading.
- Steps, edges, pillars and other transition points highlighted with yellow paint.
- Handrails to help with mobility.
- Tactile trails – dado rails or other textured materials at hand height that students can follow to find the route to a particular location in school – e.g. toilets, dining hall.
- Different floor coverings for different areas of the school to indicate a change of environment.
- Clear panels on doors so people can be seen approaching from the other side.
- A distinction between quiet and active areas in the playground, and shaded areas for students with light sensitivity.
- Sensory gardens
- Well-maintained grounds, free of obstructions
- Corridors, cloakrooms and classrooms kept free of obstructions

Other things that help blind and visually impaired people navigating their environment:

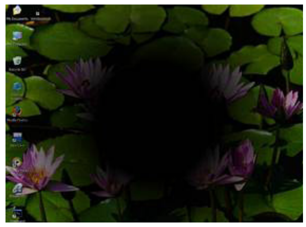
The white cane is an international sign for the blind and visually impaired. Primarily it aids its user to scan their surroundings of obstacles or landmarks.



Hemianopia



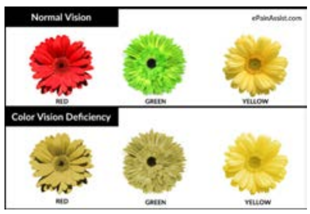
Hemianopia - macular sparing



Macular degeneration

Diabetic retinopathy

Diabetic retinopathy



Normal vision vs. Colour Vision Deficiency

Guide dogs assist blind and visually impaired people with going their way safely and independently. The guide dog is specially trained in:

- Navigating past obstacles on a walking path, both in relation to the ground and in head height (tree branches and street signs for example).
- Preventing the handler from stumbling on curbs or stairs.
- Stopping at all intersections.
- Passing streets safely by avoiding being in the way of cars and other vehicles.
- Obeying multiple orders given by the handler.

Exercises/Activities related to sensory and physical environment

Exercise A:
Touching different objects: Select different objects with different textures like soft, rough, hard, small, big, cold, warm. Use a blindfold and take turns in handling the objects.

Questions to ask:

- How is it to touch the material? Is it hard, soft, smooth, cold, warm, etc.?
- Does it have any form like round, square, triangular?
- Does the material have a smell? What does it smell like?
- Does the material make any sound when you touch it?

Exercise B:
Create a map of an area, e.g. the school hallway, the school grounds, the route to a selected location. Use something that can be felt by hand, like by gluing yarn to a paper, using paper with different texture, making raised lines by drawing on the opposite side of the paper (with a soft underlay)

Let your classmate figure out how to use the map.

This exercise is possible to work collaboratively with the visual arts teacher.

Exercise C:
Optional approach (for younger students / more time-consuming): Divide the students in the classroom in groups of two. One is the observer and the other one is the student who will experience different objects. Use a blindfold for the student who will experience and objects. Select different objects with different textures like soft, rough, hard, small, big, cold, warm. The observer students will give one object at the time to the student with the blindfold and try to note all observation during the activity about the experience of the student with the blindfold.

Discussion - Is your school accessible for visual impaired or blind students? What do you think that will make a building accessible?

These pictures show contrasts created in the environment to help the visually impaired. In the 2nd picture, the light-grey gravel has been replaced with darker gravel, and the edge of the sidewalk has been painted yellow.

The 2nd picture,shows that a yellow line has been painted on the steps to help distinguish between them.

The path leading to the reception desk is marked with a contrasting darker line which also has a different texture (and thus detectable for people using a white cane).

Educational material

Computer technology

ICT (Information and Computer Technology) has enormous potential to support students with vision impairment across the age and ability range. In recent years technology has enhanced learning experiences for all children. Because of the ability to customize and adapt equipment that is responsive to the user's needs and skills, it is particularly significant as a tool in the education of students with vision impairment and other special needs. The increasing accessibility of tablets and smart phones means that blind and partially sighted students are now able to use them directly rather than having to learn to use special software or different equipment. Most students who use Braille also learn early to touch-type and use electronic books. Visually impaired people can enlarge the text on the screen or use screen readers and speech synthesizer to read the text.

Here is a list of equipment and software available to visually impaired people (the list is not exhaustive):

Screen reader: software that makes text accessible for blind and visually impaired people by reading like speech synthesizers or Braille devices

Braille display: The Braille display is a tactile reader that connects to any PC and allows tactile access to Braille texts in real time

Braille embosser: a braille embosser is an impact printer that renders text as tactile braille cells

Screen Magnifier: software that interfaces with a computer's graphical output to present enlarged screen content. By enlarging part (or all) of a screen, people with visual impairments can better see words and images.

Speech synthesizer: Speech synthesis is the artificial production of human speech, and a sythesizer is a computer system that can read text out loud.

3D printer: 3D printing can be useful to illustrate or explain to the blind, e.g. the layout of a building or an apartment, different types of architecture, geography, or 2D illustrations and artwork

Didactic Materials and Methodology

Accessible teaching/learning/educational materials.

Accessible educational materials are print and technology-based educational materials, that are designed or converted in a way that makes them accessible for the blind and visually impaired student. It may open doors to teaching and learning that ordinary print-based materials have closed.

The materials include:

- Electronic textbooks/digital text
- Large print
- Braille
- Tactile books
- Swell-form tactile graphics

Electronic textbooks/digital text provides electronic content that is presented on a computer or another device. It may be changed in many ways (e.g., fonts, size, colours and contrast) to accommodate the needs and preferences of the student. Supported reading software with text-to-speech can provide audio and visual components.

Large print is generally defined as 16-18 point or larger font size. It provides the same content as standard print. Large print may be printed on pages that are the same size as a standard textbook page or on pages of larger size but preferably not as big as A3. Font type should be a clear font such as Tahoma, Verdana, Arial or other sans-serif fonts.

Braille

Braille was created by Louis Braille in 1829, who had himself lost his sight as a result of a childhood accident. It is a tactile system of reading and writing used by blind and visually impaired people who cannot access print materials. Braille is made up of raised dot patterns for letters of the print alphabet. It also includes symbols to represent numbers, punctuation, mathematics and scientific characters, music, computer notation and foreign languages. A full braille cell includes six raised dots arranged in two columns, each having three dots. The six-dot code offers 64 possible solutions, and braille has been extended to an 8-dot code, particularly for use with braille embossers and refreshable braille displays.

Braille is read with the fingers from left to right and is perceived with the movement of the hands in a steady and fast motion across the dots. The best readers use both hands while reading in an interplay where the left hand reads the left part of the side (the line) while the right hand meets the left one in the centre and reads the line to the end. Advanced braille readers have good manual dexterity and perceive different signs well using touch.

Accessibility to various kind of material has greatly increased with the advent of computer technology. Blind people can read everything that appears on a computer screen with special braille terminals/displays, which are connected to computers. This makes it possible for them to learn without needing to print hard copies. That way, the braille follows the technology because it increases the potential for blind people to use computers to seek information in a technologically advanced modern society.

Braille Technology

Braille Displays: A braille display is a device that has a row of special “soft” cells made of plastic or metal pins. The pins are controlled by a computer and move up or down to display, in braille, the characters that appear on the computer screen. This type of braille is said to be “refreshable,” because it changes as the user moves around on the screen. The braille display usually sits under the computer keyboard.

Focus Blue 14 Braille display

Electronic Braille Notetakers: Electronic braille notetakers are portable devices with braille keyboards that braille readers can use to enter information. The text stored in these devices can be read with a built-in braille display or the device can read aloud with a synthesized voice. These devices are handy for taking notes in class, and often have built-in address books, calculators, and calendars, too.

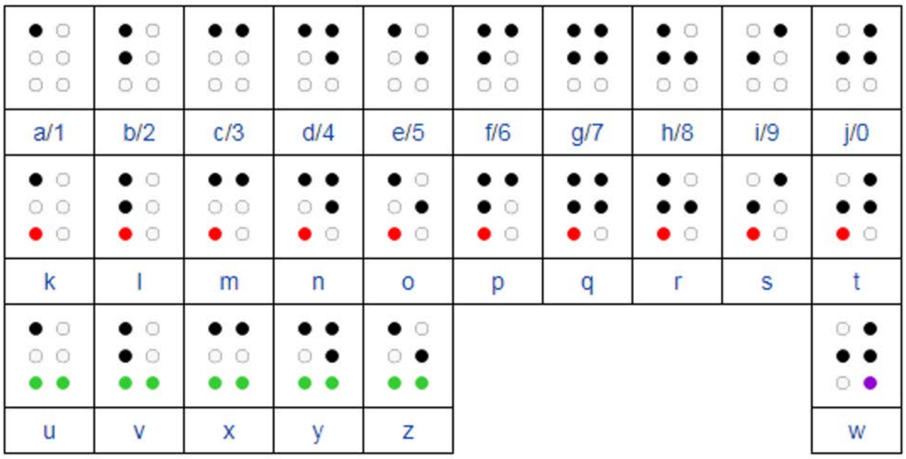
Braille Printers (Embossers): Braille printers are devices connected to a computer that do the actual embossing of braille onto thick (heavyweight) paper. They work like a regular computer printer does, in that the user can print out letters, reports, and other files from the computer.

Perkins Braille Writer

Braille writers: The mechanical braille writer works a little bit like a typewriter. It has six keys—one for each dot in a braille cell—a space bar, a backspace key, a carriage return, and a line feed key. The braille writer uses heavyweight paper (just like the braille printer) but it doesn’t need any electricity to

work.

Videos:
Louis Braille - about the inventor of braille writing.
Braille Literacy Facing Record Low Turns to Tech (Associated Press).
MOLBED Modular Low cost Braille Electronic Display.
Braille Touch Tablet and typing in Braille.



The first ten letters of the alphabet, a–j, use the upper four dot positions: (black dots in the table below).
The next ten letters, k–t, are identical to a–j, respectively, apart from the addition of a dot at position 3 (red dots in the table) :
The next ten letters are the same again, but with dots also at positions both 3 and 6 (green dots). Here **w** *was left out as not being a part of the official French alphabet at the time of Braille's life.*

Tactile pictures

People with vision impairment cannot use their sight to learn about colours, shapes, objects at home, facial expressions, illustrations, digital images, animals, landscapes, skylines, architecture, transport, etc., so they have to rely on other strategies to access information within the environment, depending on the severity of visual impairment, their age or additional disabilities.

There are different techniques for making objects and pictures more accessible for visually impaired children and methods for adaptation of materials and pictures. When someone can see only part of an object or area at a time, it impacts the way they understand the object; its properties and their common usability.

Keeping these aspects in mind, there are some methods that can make the information more accessible to blind and visually impaired people, such as tactile sensitivity, tactile books, tactile graphics.

Tactile sensitivity

Tactile books are colourful picture books which contain pictures for a child to touch. Bright colours and clear colour contrasts benefit a reader with low vision. Different materials also stimulate other senses. In addition to pictures, the books have text in both black-print and braille.

Tactile graphics are not, however, exact replicas of the original, nor are they good for fine detail and representing very large graphics.

Swell-form tactile graphics are a form of graphics created in a swell machine using a special swell touch paper. It is possible to create tactile maps, diagrams, text and graphics (mathematical tables, charts, scientific material).

Around 80-90 % of all information about the environment is coming to us through the eyes. But the sensory system is more complex, and the process of information is a combination of information captured by different sensory systems: tactile, auditory, olfactory, gustative, vibration and kinesthetic. These sensory systems are used by blind and visually impaired people as compensatory skills necessary for collecting information about objects, people, scenes within the environment.

Touch is a critical sense for the blind and visually impaired for connecting and understanding the world. Touch gives information not only about the characteristics of objects such as shape, size and texture, but also on the functional aspects of objects such as the possibility that they can be used as tools.

The transition from real objects to tactile pictures of graphics is a complex process which should be well prepared for children. Thus, there are different stages that should be kept in mind when teaching blind and visually impaired children:

- explore first real objects
- transfer the known objects in three-dimensional graphics
- transfer object within tactile pictures in books by using different textures and fabrics
- transfer real objects in tactile graphics.

In this way you support the child to develop a good representation about objects.

The best tactile books use a variety of contrasting textures and real objects. They have a small amount of text and use very simple illustrations with every aspect accessible by touch. The objects used in a tactile book are meant to represent real things and are often made of the same or similar material so that when the child touches the object it feels the same or like touching the real thing that the story is about, such as soft fabric or synthetic fur to represent a dog in a story.

The purpose of a tactile pictures book is mainly to provide additional information to the story.

Graphic images

Graphic images or pictures are used for representing different pictures, diagrams or maps to facilitate the access to information of blind and visually impaired children.

Alongside braille resources, students with little or no sight but good tactile skills may also use tactile resources, such as pictures, diagrams, charts and graphs.

Tactile pictures/diagrams can be useful when:

- a picture/diagram is not easy to describe in words
- the skill being taught requires the use of this format, e.g. maps in geography
- the shape or pattern is vital to understanding a concept
- scale is important
- the real object is unavailable

Tactile resources are often produced using heat swell paper. A simplified version of the picture/diagram is printed or photocopied in black and white onto specially coated paper. It is then fed through a heat machine that raises all the black areas. Other tactile resources can be made using ‘Wikki Stix’, tactile drawing film or embossed braille paper. Increasingly, pictures and diagrams on websites have a text description that can be read by a screen reader.

Chapter 2:
Service Learning

Service learning is an approach to teaching and learning in which students use academic knowledge and skills to address genuine community needs. It has been defined as "an educational activity, program or curriculum that seeks to promote students' learning through experiences associated with volunteerism and community service." It is seen as a way of helping students connect that they learn in school to the "real world" and as a means both of restructuring schools and "re-engaging youth" in their schools and communities.

This teaching – learning technique integrates community service with instruction and reflection to enrich learning experiences, teach social responsibility and strengthen communities. Service Learning is distinguished from simple community service by the international connection of helping activities with curriculum concepts.

Service Learning is a flexible approach that can easily be adapted to different age levels, curricular goals and community needs. Successful Service Learning projects are tied to a specific learning objective. The overall purpose of Service Learning is to instil in students a sense of civic engagement and responsibility and work towards positive social change within society.

The Benefits of Service Learning

Service Learning brings together students, academics and the community whereby all become teaching resources, problem solvers and partners. There is a flow of knowledge, information and benefits in both directions between the school and its community partners in activities. Benefits should also contribute to building social trust and social networks. Indirectly, they often have an effect toward enhanced sustainability, wellbeing and cohesion, locally and nationally, to the building of learning and knowledge-based society.

The benefit for students is in the application of academic knowledge and skills to the complexity of a real-world situation. It encourages critical thinking, teamwork, effective communication skills and self-confidence.

For teachers, service-learning offers a chance to increase awareness of community issues related to their discipline. It can create opportunities for scholarship and publication to share knowledge and identify new research areas and gives a new perspective on how learning can take place. We can say that service learning has a holistic approach and a student-centred pedagogy, and it aims to create an engaged and participatory environment, rooted in dialogue and collaboration and tied closely to the teacher knowledge.

Key Characteristics of Service-Learning

Service learning is a course of discipline-based collaboration between students, teachers and civil society partners for mutual benefits through shared learning. The nature of these dimensions should be elements for the students and their teachers´ reflections, as the service learning characteristics raise several peculiarities that cannot be avoided.

Service learning involves three key elements: a classroom element, a service element, and a process of reflection that connects all aspects together:

- it is a form of experiential learning
- it focuses on issues in a real-world context
- it must meet the needs of the civil society organization or community group
- it is academically accredited: students earn credits for their work.

Overview and focus

Service learning is a learning-teaching method in which students use academic knowledge to address genuine community needs.

What are the benefits of service learning?

How can we implement service learning in the classrom?

Difference between service learning, volunteering and work placement:

- Work placement involves the student as the main beneficiary. It is accredited and the goal in student learning, but reflection is not always essential.
- During service learning (direct or indirect) both the students and the community partner are mutual beneficiaries. The student receives academic credit, while the process meets the community need. The relationship is an equal partnership and reflection is the core to the process.
- During volunteering, community organization tends to be the main beneficiary. It is not always accredited, and the reflection is not essentially a core element.

Implementing a service learning project - stages of service learning

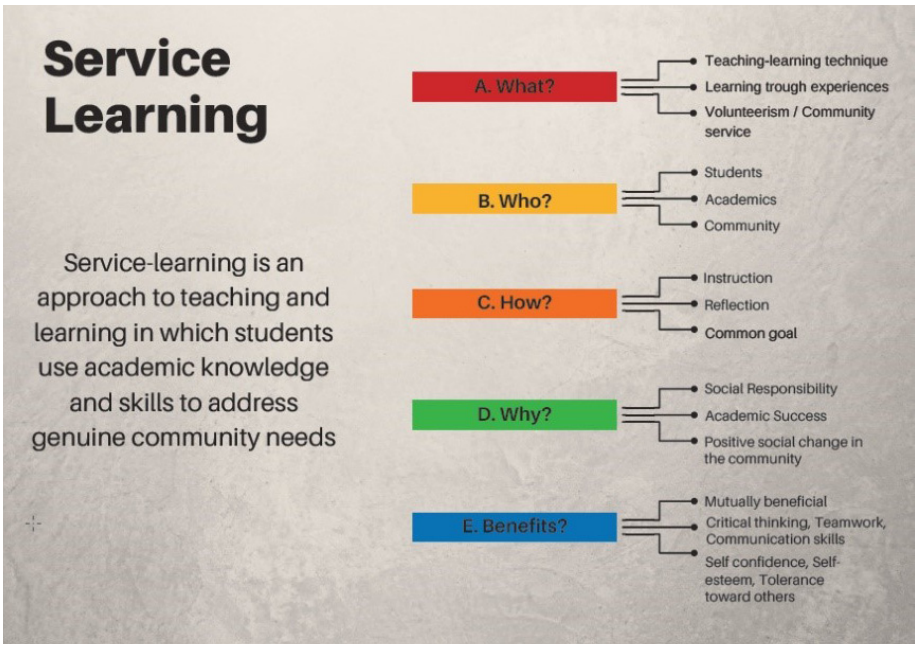
There are a lot of ways to help and get involved in Service-learning. It is a process to connect learning in the community, through five stages:

1. Investigation (community needs)
2. Preparation (student-teachers-community)
3. Action (direct service/indirect service/advocate/research)
4. Reflection (How do you want to accomplish your goal)
5. Demonstration

Video:
Stages of Service Learning

Introduction of service learning into the curriculum

The introduction of service learning into the curriculum is a process. It begins with a community partner identifying their needs or issues in cooperation with teachers. Students may sometimes have an existing contact and be able to suggest a partner. Then, students are briefed and provided with inputs such as the opportunity to hear from students who have been involved in similar activities previously. The group of students works together to design a project plan while ensuring the consultation and knowledge exchange are applied to inform the project. With the plan set up, you need to agree the way forward with your partner. At this point, a learning agreement should be developed and signed.



Strategies and methodology

Learning outcomes

Learning outcomes should be:

- Achievable, observable, measurable and assessable
- Academic, vocational, personal, civic
- Content, product, and/or process focused

At the end of a service-learning module the student will be able to:

- Demonstrate his understanding of the course content and theory of the subject through development of suitable
- Develop his problem-solving, consultation techniques, teamwork, organization, digital literacy and effective communication skills
- Reflect on the content and effectiveness of his service-learning project through the reflective journal.

Designing Student Assessments

- How do you think students could demonstrate their achievement of learning outcomes?
- Does this require a different form of assessment for module or could an existing assessment be revised?
- What type of strategy would you apply?
- What techniques will you use? How many?
- How should elements be weighted?

For each assessment technique consider:

- The criteria you will use
- Whether this element will be graded or not
- What are the criteria for community engagement?
- Who should be involved in assessment?
- Can you bring in the community service organization to support this process or peers?
- Should the work be individually assessed or as a group?
- How would you get the student to reflect on the experience?

Evaluation

Evaluation needs to be built in when the project is about to begin in order to establish the perspectives of students and community partners before and after the service-learning activity.

- Introduce some form of mechanism to capture and apply feedback and recommendations from the community partner in outcomes.
- Get feedback from the students (possibly using an online survey) asking them to reflect on practice plus the level or type of learning experienced.
- Reflect on your own experience: what worked, what didn't and how might you improve or build on a program.

Quality standards

Researchers and pedagogues in the Europe Engage Erasmus+ project have identified the essential features and quality standards for service learning (for the full document and detailed description of the quality standards see Stark et al., 2016, in Appendix).

Essentials of service-learning activities are indicators shared by scholars and practitioners both on a global scale and in different kinds of higher education institutions, and they may serve as a ground rule for service-learning quality.

The essential features of service-learning are:

1. Meeting actual community needs so service-learning meets both real world challenges of the community/relevant community partners and will be meaningful to student participants as well.

2. Service-learning is relevant to the study program. This requires active involvement of teachers/academic staff, systematic integration in study programs and the option to be recognized for students.

3. Service-learning facilitates active, regular and ongoing student reflection guided by teaching personnel and/or community partners. Reflection should lead to the understanding of diverse perspectives inherent to challenges.

4. The main learning setting in service-learning is located outside the classroom in real world settings of community partners (such as schools, community centres or initiatives).

Identify a community need for your service-learning activity

Community need is defined as a difference between the desired state and the current state of the community. Identify the needs of the community that will be met through your service learning placement.

What needs in your community might be addressed by service learning activity done by your students?

Who would determine what these community needs are?

The community partner should determine what services are needed.

Video:
Service-learning students in Hong Kong identify a problem among blind and visually impaired bowlers, and explain the process towards a solution.

Exercises/Activities

Think of 3-5 important places or places of interest in your area/country that should be accessible / more accessible to the blind or visually impaired (could be an airport, a historical site, a museum, an official building). How are they already accessible (if they are), and what could be improved?

Ideas for questions to ask: Is the place easy and safe to navigate for people with little or no vision? Does it have information written in braille or large letters, or audio guides? Should it have?

Prepare service-learning activities

1. Meaningful and relevant
2. Goals and needs defined by community partners
3. Tools we use to enable students' groups to actively design and plan service-learning activity
4. Support and coaching
5. Service learning activity linked to the community
6. Time frames (active time, expected preparation time, time for reflection)
7. Role (responsibility, preparation, orientation of students, supervision, reflections, evaluation)

Service learning experience in Iceland

Making tactile books for blind children

The National Institute for the Blind and Visually Impaired in Iceland lead a seminar for a class of 9-year-old students in Lindaskóli Elementary School in 2010, and again in 2011. The service-learning project centred around making tactile books that would benefit blind and visually impaired children and be at the same time a teaching and learning method that the students would benefit from. The students got a blank hardcover book and all kinds of textiles and material and were asked to follow specific instructions to make a simple story and then make a tactile book around the story. The students participate actively in the whole process, from deciding on the topic for the book, helping to collect and gather the items to illustrate it, telling the story, and putting it all together.

In the beginning of this process the students met a blind girl who showed them how she reads a tactile book. They were able to ask her questions and get a feel for how a blind person uses senses other than their sight to read a book.

Guidelines for the project

The students had to follow specific guidelines:

- Braille print in a normal size, 1,5 line spacing.
- The text is on the left side of the book, and pictures on the right side.
- Do not make the story too long (the book should not be longer than 5-6 pages).
- The printed (regular) text is put at the top of the page, then the braille print on top of it (embossed on see-through laminate).
- Pictures should be simplified and give the reader a good oversight. The picture should represent something told in the story. When making the tactile picture you need to make it so that the reader can use other senses (sense of touch, sense of smell esc.) than sight to "see" and experience the picture and in that way understand the story.
- Front cover: The name of the story on top, name of the author, name of the illustrator (who made the tactile picture), publisher.
- Page number at the bottom of every page.
- The books are bound by large spirals/coils; the front-page cover is made of thick paper in colour. The inside pages are made of strong paper.

After the project - Reflection

After having completed the service-learning project the students were asked to reflect on their experience in making tactile books for the blind.

They all agreed that the project had been fun and enlightening. Few had ever known a blind person and the project made them open their eyes to the fact that we all do not "see" things in the same way. There are other senses we can use to read and the students themselves enjoyed reading the tactile books using only their sense of touch, sense of smell and so on.

This service-learning project was seen as very successful; the student learned to be more open-minded, learned to make something for someone else's benefit and the visually impaired and blind children who got the new tactile books were also very satisfied with them. In fact, some of the books that the students made are still in use by blind and visually impaired children.

The students of Lindarskóli, with their teachers.

Chapter 3:
3D printing

3D printing or additive manufacturing is a process of making three-dimensional solid objects from a digital file. A 3D model is either created from the ground up with 3D modelling software or based on data generated with a 3D scanner. There are several ways to 3D print. Some methods use melting or softening material to extrude layers, others cure a photo-reactive resin with a UV laser (or another similar power source) layer by layer.

All these technologies are additive, differing mainly in the way layers are built to create an object, as opposed to subtractive manufacturing which is cutting out /hollowing out a piece of metal or plastic with, for instance, a milling machine.

3D printing enables you to produce complex (functional) shapes using less material than traditional manufacturing methods, or to create a prototype of a design. It can be more precise than subtractive manufacturing, especially for prototypes or items not meant to be mass-produced.

3D printers can be bought pre-assembled or as a DIY 3D printer kit for those who are interested in making themselves familiar with the hardware.

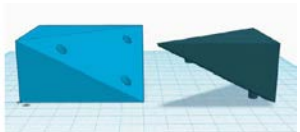
Complicated geometric shapes can also be useful for math lessons, to explain and calculate shapes that are made of several different geometric shapes, such as cones, globes / half-globes, or cylinders.

3D printing for visually impaired people

3D printing can be useful to illustrate or explain many things to the blind or visually impaired, that most people would otherwise rely on their eyesight to understand better. It may be the layout of a building or an apartment, different types of architecture, archaeological items, geography, or 2D illustrations and artwork.

Tactile pictures and 3D models need to be simple because the visually impaired do not have the same overview as sighted people but must read one part at a time and then put them together in their mind to realize the big picture. Too many small details will not help the understanding.

Examples of how 3D printing can benefit the blind or visually impaired include geometrical shapes for mathematical studies and archaeological findings replicated to help in history lessons. The Swedish National Agency for Special Needs Education and Schools (Specialpedagogiska skolmyndigheten, SPSM) gives an example of a 10-year-old student whose history lesson is covering the Iron Age. To better illustrate how people lived, what they were wearing, and what artefacts they created, **the teacher has developed a box of 3D-printed models** of real archaeological finds that have been found at historical sites in their local area. The students are asked to select three findings per group and discuss what they think the objects were used for. While 3D replicas may benefit the whole class, they allow the blind to actively participate in the discussion, when a picture could not.



For more advanced technology, a small chip containing additional information on the dimensions of the objects which can be read using a mobile scanner, can be attached to the object. By doing so, the blind student has access to more information than necessarily written in the math book, but similar to their sighted fellow students.

The Tactile Museum in Athens, Greece, has a number of replicas of ancient pieces of art and history for students to touch and feel, where the original artefacts would be securely stored in a glass box. Among their items is the enigmatic Phaistos Disc from the Minoan Bronze age, which is covered on both sides with a spiral of stamped symbols, and a cylinder showing examples of geometric patterns on the surface of vessels, the originals dating back to around 700 B.C.

ONCE Typhlological Museum for the Blind (built in 1992) offers exhibits of typhlological material which can be felt through the sense of touch. It houses a collection of scale models of well-known monuments both international

and national. The models shown are for instance the Eiffel Tower in Paris, the Sagrada Familia in Barcelona, the Colosseum in Rome, the Taj Mahal Palace in India and many more. The museum has been designed to promote and bring culture closer to those who are blind and visually impaired. It also retraces the history of Braille and other accessible writing systems that have been used in teaching blind people through the ages.

Videos:
Snapshots from visit to the ONCE museum (Erasmus+ 3D printing.)
Blind man guessing 3D-printed objects of oversized things

Technical description of two different types of 3D-printing

There are several techniques and materials to choose from if you want something 3D printed. The following comparison and pictures in the sidebar are taken from The Swedish National Agency for Special Needs Education and Schools' **report of the possibilities of 3D printers.**

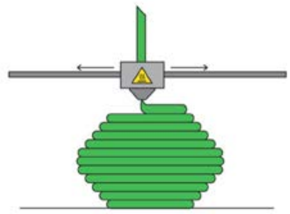
The most common method for home use and small-scale manufacture is called Fused Filament Fabrication (FFF) or Fused Deposition Modelling (FDM). With this technology, the objects are printed out layer by layer with molten plastic (filament) which is fed from a large coil through a moving, heated printer extruder head. Imagine one tiny computer-controlled glue gun. Another method is called Selective Laser Sintering (SLS) and builds up the model using fine plastic powder which spreads evenly over the platform and is then cured with laser where needed. It is the same principle with bearing-by-bearings, but with the laser achieves greater detail than Fused Filament Fabrication.

One of the biggest difference between FFF/FDM and SLS is the support . The model built with powder (SLS) has support during the process in the form of all powder that is not cured and packaged tightly around the object.

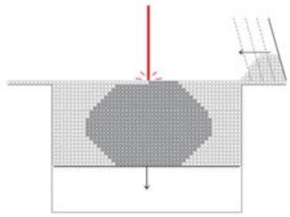
With the FFF method, the model is at risk of losing quality when it comes to "building bridges" and the method often has limited possibilities for adding necessary support material when printing complex models.

However, when it comes to user-friendliness, the FFF printer is a winner. You can quickly and easily print small gadgets when you feel like it. With the laser printer it is best to wait until you have prints to fill the entire building surface, as it may otherwise feel a bit like a waste of time and resources to launch the entire machinery for a pair of earrings, for example. Also, by using an FFF printer you don't need to handle a large amount of powder running the risk of it ending up all over the place, with hitherto unresearched health aspects.

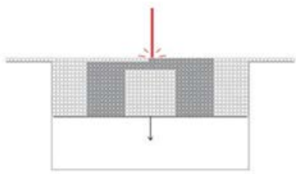
Another reason to stick to Fused Filament Fabrication is the size of the printer. As for now, the laser printer is the size of two refrigerators and costs about 115,000 EUR. Despite its size, it has no more than double the building surface compared to a medium size FFF printer. But the quality is fantastic and the ability to make multiple prints simultaneously has some benefits. At the same time, it is more expensive even when it comes to materials and operations to print on one SLS machine compared to an FFF.



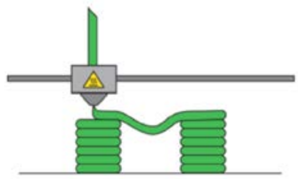
Principle of how an FFF printer spits out hot plastic in stock.



Principle of SLS technology. Dark gray circles represent hardened powder.



Here, a "bridge" of nylon is built in SLS printers. The powder under the hanging part holds the bridge in place while the plastic cures.



A bridge is built in an FFF printer. The warm plastic is soft when it is sprinkled out and hangs down. The bridge becomes uneven and not exactly according to the computer model.

Starting points:

There are many opportunities to utilize the 3D technology for people with visual impairment.

There are already a lot of tactile materials like are developed in different ways for pupils in the younger grades. In this project, we have targeted ourselves mainly on students in upper secondary and upper secondary school, and above all focused on things that can strengthen teaching in mathematics and science. The examples we present are predominantly from a mathematics book called Mathematics 5000, but also examples from chemistry, history and others substances occur, as well as a number of leisure activities, to give inspiration on broad front.

Besides printing at home or at school, there are some companies that offer 3D-printing service. That may be feasible for printing a large batch or very detailed objects, but it may be relatively much more expensive for small or single items, and may take much longer to get.

Where and how to start?

It all starts with the creation of a 3D model in your computer, or getting one online. There are several open-source websites like **Thingiverse** or **MyMiniFactory** where users can download ready-made files. Creating a 3D model from the ground up requires either 3D modeling software or a 3D scanner. A 3D scanner enables you to create a digital copy of an object, by generating data of the item scanned.

Videos:
3D Now's Ultimate Beginner's Guide to 3D Printing, part 1 (11:23 min.), covering file types, slicing types, single and dual extruders, bed types, and more:.
3D printed Eiffel tower time lapse (5 min. video, but in real time it took about 20 hours to print).

3D Scanners: Currently, prices of 3D scanners range from expensive industrial grade 3D scanners to cheap DIY scanners most people can assemble at home.

3D Modelling Software

Software for 3D printing can be either industrial grade, which may be costly but has better customer support or may be more user friendly, or free open source software. We recommend comparing different 3D modelling software.

Tinkercad is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.

FreeCAD is another popular open source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.

Videos:
How to pick the right 3D printing software.
Practical things – "**13 things I wish I knew when I got started**" (34 min.).

Choosing the right 3D printer

Cheap 3D printer kits can be a great starting point, but there are many factors to consider before deciding what 3D printer is best suited for you and your needs. Will it be used in the classroom? Will it be used for small batch production?

An online list of currently available 3D printers can be useful to compare price and get familiar with different features.

Videos:
Tinkercad:
Tinkercad's beginner's tutorial – more detailed than the website's tutorial/ exercises. Good for getting familiar with the basics.
Making organic shapes on Tinkercad.
Scan a drawing, convert to .svg-file, and import into Tinkercad.

FreeCAD:
Learn FreeCAD by Elwirak (YouTube channel)
The part design workbench (55 min.)
A crash course (18:49 min.) in the design of a part in FreeCAD and printing it on a personal 3D printer.

Other:
Fusion 360 tutorial for absolute beginners (part 1)

3D modelling software are often made to suit the functions of the user's industry, which has resulted in the rise of software suited to specific niches. Software applications that cater to aerospace or transportation, furniture design or fabrics and fashion among many others are currently on the market.

According to G2crowd, these were the best free and open source CAD tools in 2018:

1. FreeCAD
2. Fusion 360
3. Onshape
4. nanoCAD
5. OpenSCAD
6. Tinkercad
7. 3D Slash
8. LibreCAD
9. DraftSight
10. QCAD

Their review includes a short description, pricing, and features for each program.

Additional comparison, reviews, and more:

- **Comparison of free CAD software programs for 3D printing** (May 2018)
- **Top 25 of the best free CAD software** (Oct. 2018)

Slicing: From 3D Model to 3D Printer

When you have a 3D model, the next step is to prepare to make it 3D printable. Using a process called slicing, a 3D model is prepared for printing. Slicing divides a 3D model into hundreds or thousands of horizontal layers, using a slicing software. When your 3D model has been sliced, it can be fed to your 3D printer. This can be done via USB, SD-cards or Wi-Fi, depending on the type or brand of the printer

3D-printing materials

3D printing technology can be used with various materials, such as UV curable resins, waxes, ceramics, metals, polymers, and thermoplastics.

Additive Manufacturing processes are classified into 7 categories:

- VAT Photopolymerization
- Material Jetting
- Binder Jetting
- Material Extrusion
- Powder Bed Fusion
- Sheet Lamination
- Directed energy deposition

For further explanation on each type or process, visit this webpage, on printing technology.

Creating 3D objects for the blind - things to consider

Recruit or get help and advice from support staff, if possible. Support staff, to people with any impairment, have an important role to play in teaching concepts and methods. Support staff should explain why things are done in a particular way and how effective objects and documents should look.

The students creating the 3D model will likely be sighted and may need a certain adaptation to the needs of their blind co-students. They may not immediately realize what the blind or visually impaired find lacking or unclear, and it is important that they be included in the process. Work with the blind/visually impaired, not for them.

Since the printed objects are likely to be handled a lot, keep in mind that the parts of the **printed object cannot be too fragile or too thin** (e.g. tree trunks on a map).

The **texture of a finished print object is much rougher than paper**, so be careful that the information (text or drawing) consists of lines not too fine and stand high enough to be readable. Don't overdo it, though. People who rely on their fingers to read text and information usually develop a keen sense of touching in one or more fingers.

To generate braille, the **TouchSee**-website can be very useful. The websites allows people to write text and convert into braille, and save as an .stl-file which can then be added to a 3D-file created in Tinkercad or FreeCAD. When adding written information in braille, keep in mind that **the text may take up more space than expected**, especially compared to written text intended for the sighted, which can be scaled down to be relatively small.

While Braille needs to be raised, **be careful not to raise it too much** as that can be confusing – see the example in the picture below. People who read Braille with their fingers usually develop a good sensitivity in one or more fingers.

Creating a computer-based 3D model of something detailed and complicated can be quite challenging, and we recommend that students' task/expectations be kept realistic. It is seldom a good idea to start with a project so ambitious that it will end up nowhere near completed. But it might be a good idea to show students what can be accomplished with a lot of practise and training. Eva Sbaraini's 3D model of Le Petit Prince is a good example.

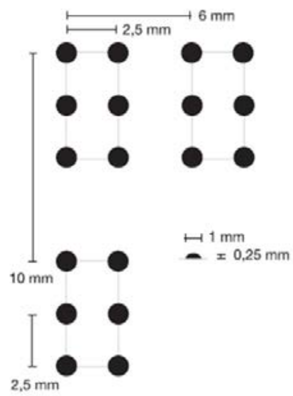
Keep in mind:

3D printing takes a long time. While a small item might take less than half an hour to print, a large one might take 12 hours or longer.

Braille needs to be printed sideways or slanted (with FFF printing), otherwise the dots will be too flat or too unclear.

Braille doesn't need to be printed on the items every time; labels or stickers in braille (to be added afterwards) may be just as useful.

(Handheld braille labeller from Braille Bookstore http://www.braillebookstore.com/Handheld-Braille-Labeler.1)



Le Petit Prince by Eva Sbaraini.

Interesting articles and material:

- **4 ways 3d printing is helping the visually impaired "see" the world**.
- **10 ways 3D printing supports the blind**
- **MyMiniFactory** – over 60,000 free and paid 3D printable objects

Ideas for exercises:

- Find out if your town/city has floor plans of buildings or apartments available online.
- Find a floor plan (any floor plan). How much information do you think is essential? How many details (if any) do you think can and should be removed? Discuss.
- How small do you think writing in Braille can be, in order to be read by fingers?

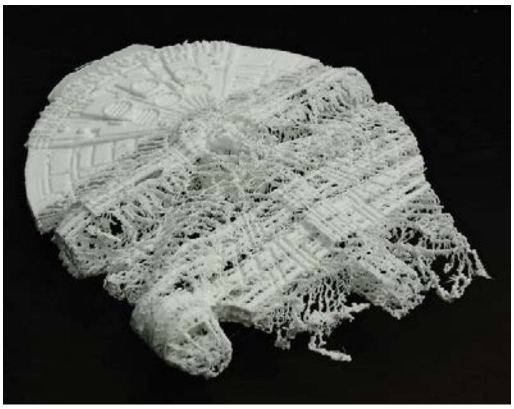
Teacher collaboration

The teacher of design technology should attempt to meet with a qualified teacher of children with vision impairment to better understand the needs of a particular student, or the visually impaired in general, and find out how much support they are likely to need for different practical tasks.

3D printing gone wrong

As will all crafts and technical devices, things can go wrong despite the most careful precautions. This applies to 3D printing as well and in the Flickr-community, a group by the name of **The Art of 3D Print Failure** is pooling pictures of 3D-printing gone wrong, often with amusing results. Below are a few photos by members of that group.

The text on the picture reads: "#3DBenchy printed with too thick layers causing the outer shell perimeter to detach from the inner."



Student projects: A, B, and C

This part consists of three projects for students to work on.

Project A is the least complicated and is planned with the youngest students in mind, or ones with a limited attention span. Project B requires more planning and has a room for development if the teacher feels the students are up for it. Project C probably requires the most planning, and students are encouraged to arrange for a user testing before presenting the final result to find out if it is as useful as they hope, or if they may have overlooked something.

Each project is divided into several sessions, but depending on each group of students, one or more sessions may need to be divided up (split in two). Each project lists a few useful or interesting websites and videos, and Appendix II includes a more extensive list, which teachers are encouraged to check out.

Resources: For this implementation the following will be needed:

- Computer
- Network connection
- Tinkercad account, or CAD-software
- 3D printer
- PLA (plastic for printing)

Project A. Sign or marking

Project: A sign to mark specific places or to help blind or visually impaired people navigate. For example, a sign for WC, library, cafeteria, library, or any other place people are likely to look for (think of icons or pictograms).

The goal for this project is to introduce students to 3D printing, social inclusion, and visual disabilities through playfulness and by sparking their interest in technology. This is the simplest or easiest project of the three; make it fun!

Through this project, students will learn about designing 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or visually impaired, and how society can help include people with disabilities.

Session 1: Introducing 3D printing

Preparation: Teacher chooses 12-24 small models (ready-made STL or SLA-files) for students to pick from. Before the 2nd session, selected items will be printed. The idea is for students (young, or with limited attention span/sense of time) to see the results of the 3D printing process as soon as possible.

Ready-made models can be found here, among other places:
Thingiverse - *a website where user-created digital design files are shared for free (https://www.thingiverse.com/)*
MyMiniFactory – *over 60,000 free and paid 3D printable objects (https://www.myminifactory.com/)*

The first session introduces 3D printing; what it is, what can be created, and what it is currently used for (engineering, design prototypes, fashion, aeroplanes, medicine, and more.). It might be a good opportunity to discuss how blind and visually impaired people "see" things, and how they need to feel their way around more than sighted people do (perhaps show video 1).

This might also be the best time to briefly explain what service learning is, and how the students' work may benefit other people (video 3).

Useful / interesting videos:
1. **Blind man guessing 3D-printed objects of oversized things**
2. **3D printed Eiffel tower time lapse** (5 min. video, but in real time it took about 20 hours to print)
3. **Stages of service learning**

Students get to pick one model each from the 12-24 pre-picked by the teacher. These models will then be printed before the next lesson.

Session 2: Introducing the printing process, and identifying a need.

Preparation: Teacher prints the 3D models picked by students during last session.

Students get a time to examine and play with the printed objects, and discuss how the objects can be used, developed further, or personalised.

Identify a need: Is there something at school that needs a better sign? Is there any object for lessons that blind students lack or would benefit from having? Look for pictograms on the internet. Could they be used or improved for this purpose?

Students discuss areas or places that would benefit from a clear or better sign or marking. Collectively pick 1-2 projects to draw/sketch during the next session.

Session 3: Sketching and brainstorming

Preparation: Teacher finds and gets familiar with software to turn 2D images into 3D Inkscape for example (see links below).

Useful / interesting weblinks:

- **Tinkercad** is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- **Tinkercad: Learn how to import .svg to Tinkercad**
- **Braille standards for 3D** (size, height, spacing, and more.) **Also here.**
- **Inkscape: Learn how to vectorize image using Inkscape** (turning a 2D drawing into a 3D model)
- **Teaching material from Fab Academy** about 3D printing and 3D scanning
- **Accessible Maps for the Visually Impaired**

Students sketch their ideas for the sign or mark the group decided on. Encourage students to come up with multiple solutions (literally, brainstorm), and discuss what might or might not work, and why.

Pick one solution (or possibly two) to either 3D print, or to work further on or refine. At the end of this session (or session part), the teacher should show the students how to change a 2D image to a 3D model, using computer software.

Steps:

1. Draw on white paper with a black marker (sharpie)
2. Scan
3. Import image to Inkscape trace bitmap and turn image to vector
4. Save as .svg in Inkscape
5. Import .svg model to Tinkercad
6. Edit model in Tinkercad
7. Export as .STL
8. 3D print

Before next session: Print the object.

Session 4: The final product

Preparation: Teacher prints the motif / sign designed and 3D-modelled during previous session.

Now it's time to paint raised lines/parts of the product, if possible and if needed. When the paint has dried, present and explain the final product to a group of fellow students.

Drawing from experience:

In the Valencian school IES Benlliure, a student in the Design and 3D printing course created a sign for the school's toilets (WC signs). At first the design looked like a standard WC sign, a human form indicating a female (woman in a dress) and another one indicating a male. The sign consisted of a black background and a yellow icon/picture. After a feedback from a visually impaired person, who explained they were finding it difficult to tell the male and female forms apart, the designs were changed. The human form was omitted and the female and male figures took on a more styliesed look in the form of a triangle and a circle; a triangle pointing upwards indicating a female dress while a triangle pointing downwards indicating a masculine shape of broad shoulders and a narrow waist. A circle marked the figure's head on both symbols. The background was changed from black to white, and the figures' colour from yellow to black. The added contrast makes it easier for people with different types of visual impairments to recognize the forms.

Project B. List of bus or metro stops

Project: A list of bus or metro stops, or a map of bus/metro system.*

The goal for this project is to introduce students to 3D printing, social inclusion, visual disabilities, and to design a simple diagram to help visually impaired people navigate. It is equally important for the seeing and the visually impaired to experience independence, and maps like this may help the latter navigate the public transport system. While it is useful to have oversight of the whole system, creating a complete map of many lines or routes may be too complicated and difficult to understand. Therefore, it might be best to start with making single [bus/metro] lines.

Through this project, students will learn about designing 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or visually impaired, and how society can help include people with disabilities.

* **It depends on the group** if the solution is to design a description for one bus/metro line, indicating where to transfer or change lines, and other important spots, or if the final project will be a map of more lines, or a route from A to B with one or more switches on the way.

* **Be aware** that the time each session takes may vary greatly between groups, and some sessions may need to be split into two parts.

Session 1: Introducing 3D printing

The first session introduces 3D printing; what it is, what can be created, and what it is currently used for (engineering, design prototypes, fashion, aeroplanes, medicine, and more). It might be a good opportunity to discuss how blind and visually impaired people "see" things, and how they need to feel their way around more than sighted people do (perhaps show video 1).

This might also be the best time to explain what service learning is, and how the students' work may benefit other people (video 3).

Useful / interesting videos:

1. **Blind man guessing 3D-printed objects of oversized things**
2. **3D printed Eiffel tower time lapse** (5 min. video, but in real time it took about 20 hours to print)
3. **Stages of service learning**

- Discuss visual impairments and problems visually impaired people might encounter.
- Discuss what information would be needed and are relevant on each map or access guide. How can we avoid too much information on one map?
- Discuss how the blind and visually impaired get around and problems they might encounter with public transportation.

3D modeling software: Computer Aided Design (CAD) programs

There are many types of 3D modeling software available, both commercial software and free open-source programs.

For beginners we recommend using **Tinkercad**, but more advanced users might prefer either **Fusion 360** or **FreeCAD.**

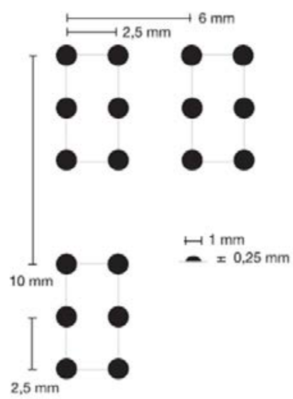
Useful/interesting weblinks:

- **Tinkercad** is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- **FreeCAD** is another popular open source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.

More useful/interesting videos:

- **Service-learning students in Hong Kong** identify a problem among blind and visually impaired bowlers, and explain the process towards a solution.
- **How 3-D printed skull plates are revolutionizing surgery** (less than 2 min.)
- **3D Now's Ultimate Beginner's Guide to 3D Printing**, part 1 (11:23 min.), covering file types, slicing types, single and dual extruders, bed types, and more
- **Practical things** – "13 things I wish I knew when I got started" (34 min.).

Session 2: Sketching and brainstorming



Choose a route (direct bus/metro route, or a route from a specific place to another) to transfer into tactile information.

Depending on the size of the map, the names of stops may need to be shortened. The name of the London station Hammersmith & City, for example, is too long. A shortened version could be "Ham./City." Make sure to look into the right size of braille cells.

Begin sketching on paper (or brainstorming), to discuss further next session. Discuss potential problems/challenges in the design process.

Session 3: Creating a 3D model and printing

Continue sketching if needed.
Discuss ideas and what might work, what might be problematic, and why.

Refine the final drawings and designs, and then move onto creating a computerized 3D-file.

Design the product using the preferred program (list of programs can be found in Appendix IV) and start the printing process.

Session 4: Finishing Touches

Hopefully, the printed piece will be done when the session begins, or shortly after. This is when the group starts gluing the pieces together (if needed), and painting outlines to make them stand out (so not only the blind but also people who benefit from their eyesight can use them).

Map of metro lines, by students of I.E.S. Benlliure in Valencia.

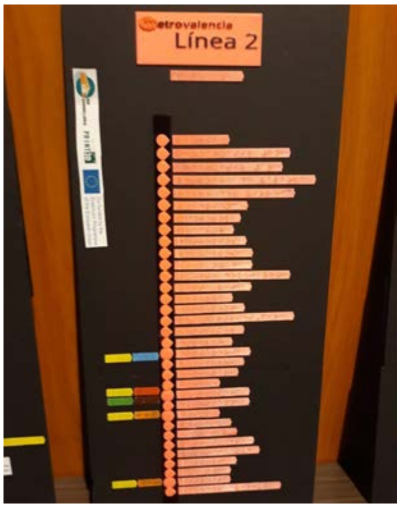
Drawing from experience:

Students from I.E.S. Conselleria school in Valencia in Spain who were taking a basic training course in IT, designed and printed a tactile version of the 9 lines of Valencia's metro system. Each line was designed so that stops with transfers were easily indicated. Names of stops were printed out in braille using the Touch See website (a braille generator). A small label with the number of the line to indicate transfers. Once the designs were finished a color was chosen to represent each line.

Session 5: Presenting the final product

The last part of the project, students should formally present the product to fellow schoolmates or a target group, and describe the process as well as they can. A formal presentation can help raise awareness about disabilities in general and it can also be satisfying to show off a work well done.

Metro stations and a metro map by students of I.E.S. Conselleria



List of metro stations, by students of I.E.S. Conselleria in Valencia.

Project C. Map of an area or building

Project: A tactile map of a building or an area

The goal for this project is to introduce students to the 3D printing, social inclusion, and vision disabilities, and to create a map to help the blind or visually impaired becoming less reliant on others for navigation information.

Through this project, students will learn about drawing and creating 3-dimensional work in computers, what can be created, limitations, and such. Students will also become aware of what it means to be blind or vision impaired, and how society can help include people with disabilities.

Keep in mind: Geographical or detailed map may show a lot of information that are unnecessary for the blind or visually impaired, and can be confusing on a tactile map. Students will have to think about what is of importance, and omit or simplify the rest. Important marks on the map might include:

- All or certain buildings
- Landmarks such as roads, paths, creeks, ponds...
- Entrances/Exits
- WC
- Gates, stairs, lifts (elevators),
- Statues, sculptures, water fountains

Students will also have to decide how they will mark or sign/symbolize different areas. Will paths around a building have different texture than the walls of the building? Will a certain shape indicate a classroom while another indicates WC's or common areas (cafeteria, library, etc.)?

Tactile maps are available through various online sources, such as Touchmapper.org or Cadmapper.com

Session 1: Introducing 3D printing and visual impairments

Introducing 3D printing; what it is, what can be created, and what it is currently used for (engineering (prototypes), fashion, airplanes, in medicine, and more).

- Discuss visual impairments and problems visually impaired people might encounter.
- Discuss how the blind and visually impaired get around and problems they might encounter finding their way.
- Discuss what information would be needed and are relevant on each map or access guide. How can we avoid too much information on one map?
- Throw around ideas of places that might be good "candidates" for maps.

Relevant video:

- **Student designs 3D-printed, braille maps**

Useful / interesting websites:

- **Tinkercad** is a free online software (no download required), and very user friendly. Their website offers simple tutorials to get users familiar with the interface and basic movements. When you have your final design, it can be exported and saved as a printable file.
- **FreeCAD** is another popular open source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well. It is much more advanced than Tinkercad, but not as user-friendly.
- **Touch-mapper:** where you can easily create custom outdoor maps for any address of your choice.
- **Cadmapper** - Instant CAD files for any location on earth - free areas up to 1 km^2.

Useful / interesting videos:

- **Service-learning students in Hong Kong** identify a problem among blind and visually impaired bowlers, and explain the process towards a solution.
- **How 3-D printed skull plates are revolutionizing surgery** (less than 2 min.)
- **Blind man guessing 3D printed objects of oversized things**
- **3D Now's Ultimate Beginner's Guide to 3D Printing**, part 1 (11:23 min.), covering file types, slicing types, single and dual extruders, bed types, and more.
- **3D printed Eiffel tower time lapse** (5 min. video, but in real time it took about 20 hours to print).
- **Practical things** – "13 things I wish I knew when I got started" (34 min.).

Session 2: Sketching and brainstorming

Choose a place or an area you believe visually impaired people might benefit from having mapped or explained.

Begin sketching on paper (or brainstorming), to discuss further next session. Discuss potential problems or challenges in the design process.

It might be beneficial to consult with a blind or visually impaired person early on in the process, to find out what their opinion on the importance of items or information on the maps.

Make time for "user testing" among blind or visually impaired people at later stages, to find out if there is anything you might have missed.

Ideas for exercises:

- Find out if your town/city has floor plans of buildings or apartments available online.
- Find a floor plan (any floor plan). How much information do you think is essential? How many details (if any) do you think can and should be removed? Discuss.
- How small do you think markings in braille can be, in order to be read by fingers?

Find a map of an area using a map-generator (e.g. Touch-mapper or Cadmapper) and decide which part should be used.

Session 3: Getting to know the printing process

Continue sketching if needed.

Discuss ideas and what might work, what might be problematic, and why. Refine the final drawings and designs, and then move onto creating a computerized 3D-file. It is now time to design the product using the preferred program (list of programs can be found in Chapter 3 and Appendix IV) and start the printing process.

Chapter 3 explains 3D-printing to a point, but it depends on each group of students how detailed the explanation should be.

Print the map before next session.

Session 4: Product assembly, painting, details

To make the maps more accessible for visually impaired people it is advised to paint the outlines (using model paint, for instance) to make them stand out from the background.

If the map is large students might need to print out sections of it and fuse or glue them together afterwards. Printing braille can be tricky; the base must be slanted and the "dots" are not always distinct enough. It may therefore provide better results to print any text in braille separately, or using labels made with a label-maker or a typewriter (using stickers).

Drawing from experience:

In I.E.S. Benlliure high school in Valencia Spain a group of 15-16 year old students created a scaled-down model of their school. They based the model on real plans of the school and made different parts to scale. They divided into separate pieces in order for them to fit the printer and then glued them together afterwards.

Floor plan made by students of I.E.S. Benlliure, Valencia.

Session 5: User testing

Get a blind or visually impaired person to test the map, and to see if they think anything is missing, too detailed, or could somehow be improved.

Depending on their feedback, discuss whether it is feasible to change the design, and how. Sometimes, changing according to feedback may prove too complicated. If that's the case, then be prepared (as a group) to explain the group's idea, the feedback, and why it could not be adjusted. This is a learning process for all, and sometimes things do not go entirely as planned.

Session 6: Presenting the final product

Complete project finessing if needed.

The last part of the project, students should formally present the product to fellow schoolmates or a target group, and describe the process as well as they can. A formal presentation can help raise awareness about disabilities in general and it can also be satisfying to show off a work well done.

Chapter 4:

Implementation of the PRINT3D project in schools

Teachers from five schools participated in the PRINT3D project, two schools from Spain and three from Greece. The students participating were age 10 – 17. Some classes were optional subjects whilst others were compulsory.

The teacher's part in the project was to implement both, technical and didactic aspects of 3D design and printing. As well as teaching students how to design and print in 3D, teachers were responsible for implementing service learning methodology into the curriculum centred on visual impairment.

Students participated in various activities during their studies to be able to imagine what it is like to be a visually impaired or blind person. Students needed to experience what it is like to use other senses than sight to "see". In order to convey this, teachers used different methods. Teacher's role was to implement the learning of 3D printing in the classroom, with the aim of generating useful objects for the visually impaired, in particular school plans.

The end result of the PRINT3D project was to design and print a 3D map and/or a Metro line that benefits blind and visually impaired people.

Teachers and students from five schools participated in the PRINT3D project; two from Spain and three from Greece. They are the following:

1. 4th Primary School of Pfkis, Athens, Greece
2. 3rd Gymnasium Kifissia, Kifissia, Greece
3. Ellinoagliki Agogi, Marousi, Greece
4. I.E.S. Conselleria, Valencia, Spain
5. I.E.S. Benlliure, Valencia, Spain

4th Primary School of Pefkis

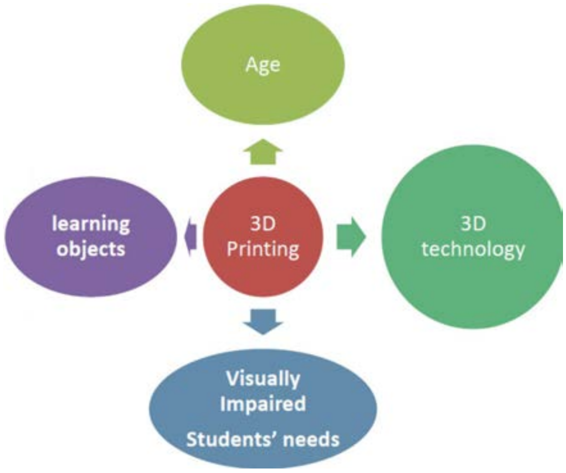
Location: Athens, Greece

Age of students: 10-12
Software/websites used: Tinkercad, FreeCad, PrintLab, Voxel Builder, Inkscape, Scratch

The goal of this project is to make students aged 10-12, design and print 3D maps of areas or metro system to help blind and visually impaired students navigate their surroundings. For example, they printed a 3D-map of their classroom.

Things that needed to be taken into consideration:

1. **Age:** The cognitive and emotional level of the students
2. **3D technology:** 3D printing is a new technology to the students
3. **Visually impaired students' needs:** The lack of awareness regarding the needs of the visually impaired students
4. **Learning objectives:** The students need to have a basic understanding of geometry to be able to design in 3D.



Having these 4 axis in mind, an action plan was implemented to prepare students for the final phase of designing and printing 3D objects.

1. Cognitive and emotional level related to students' age

a) Students were coordinated and aligned with the school's and classroom's rules.

b) They were more capable to work in groups, collaborate and take initiatives, use ICT (Information and Communication Technology) efficiently and get ready to use more complicated mathematical and geometrical concepts.

2. Introducing new 3D Technology

- First, tudents watched videos of 3D printers' capabilities: simple 3D printed objects: cars, homes, clothes, food etc.
- After each video, a discussion was initiated, and students had the opportunity to exchange views and ideas
- Symbaloo (an online bookmark accessible any time anywhere) was used to watch and comment on some videos about 3D printing.

Discussion: "If I had a 3D printer I would print…"
The students were asked to collaborate in groups of 2-3, to search on the internet for further information and create a presentation with the subject:

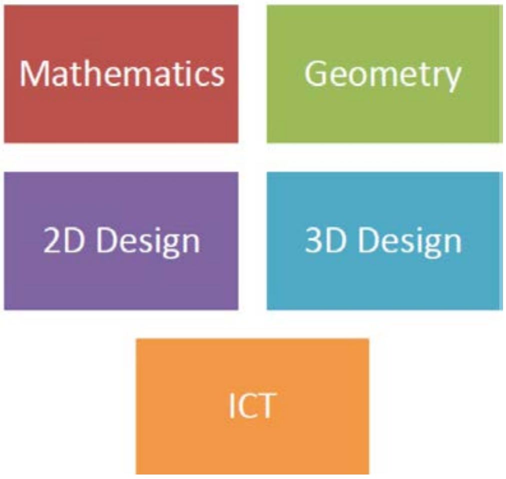
- This task revealed the misunderstanding that many students had regarding the difference between regular 3D objects, and those produced by 3D printers
- Then all the groups presented their works in the classroom
- Each presentation was discussed and given feedback
- Students begun to realize the importance of this new technology which may lead us to another industrial revolution

3. Lack of awareness regarding the needs of the visually impaired students:
Through experiential games, students tried to understand the difficulties that their visually impaired classmates could face in their day-to-day school life.


The group at the Tactile museum.

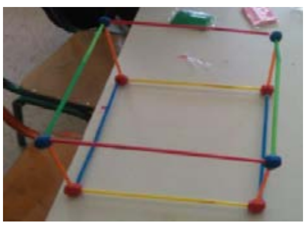
4. Learning Objectives/mathematics – geometry

- The aim of this activity was to make students design their classroom map, using a scale and multiplication tools
- They went from the 2D model to the 3D model, using paper, pencil, ruler, construction materials, and appropriate software



Activity:

a) **Two-dimensional representation of the class - Pencil, ruler paper**
Students calculated the dimensions of the classroom and desks using a scale of 1/40 and drew a map of the classroom on millimeter paper.


Starting our constructions using plasticine

Video:
Scratch Tutorial on YouTube

b) **Two-dimensional class representation - Scratch Programming Tool**
Students used **Scratch** to draw a 2-dimensional plan of their classroom

c) 3D representation of the class - Construction materials
Students used plasticine and straws to build a 3D models of the classroom.

d) **3D representation of the class - Digital 3D design software**
Students uses measurement's to design the classroom in 3D. One block was equal to 50 cm. The students used **Voxel Builder**, an easy cube-based 3D design web tool with DIY 2D/3D printing.

Importing a picture using Inkscape:

Inkscape is a free and open-source software and vector graphics editor can be used to create or edit vector graphics such as illustrations and diagrams. Students were asked to find pictures of Greek islands and convert them into 3D design, add braille names and print them. The students imported a line drawn picture they found in Google and imported it into Inkscape. Next the students converted the picture into a svg image, saved the new image and imported it into FreeCAD. Then they extruded it making it 3D and saved it as an .stl file.

Video:
Inkscape Tutorial on YouTube

Creating a map:

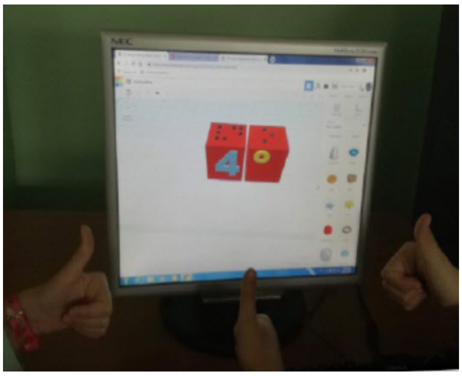
The students used **Touch mapper** to download a stl map of their neighbourhood without buildings. Two groups of students using this .stl in Tinkercad to add information they felt was important to a visually impaired classmate. Each group was allowed to add their own symbols.

Making a 3D model of Athens Metro Line:

Students were shown how to use FreeCAD to create Athens Metro Line. One group created a second Metro Line based on the first on FreeCAD.

Other projects:

- **Keychain with students name on it**
- **Make your school name in braille**



3rd Gymnasium of Kifissia

Location: Kifissia, Greece.
Age of students: 15 years
Software/websites used: FreeCAD, Tinkercad, TouchSee, Microsoft Paint, 3D Printing rocks, Solidworks, Autodesk Netfabb Standard 2018, Touch mapper, Inkscape, Cadmapper.

As an introduction to the Erasmus+ program "Promoting Inclusion through educational 3D – Printing" the students of B1 class, in the IT Lab, were informed, through conversation and video presentations, about blindness and what may cause limitation of vision (disease, injury etc.). They were also informed about the principles of 3D-printing

1. Learning Activities

A group of 13 students in 3rd grade participated in the 3D project. In order to get familiar with the design software (FreeCAD 0.16), the students went through many exercises and created over twenty 3D-models during the learning period. Most of the exercises were taken from **MakeITReal** and YouTube (**here is a link to 40 FreeCAD tutorials** in Spanish).

2. Athens Metro

Students created the Athens Metro and Suburban lines with Braille labels. The Athens Metro has 3 lines;

- Line 1 (green line): Kifissia – Piraeus
- Line 2 (red line): Anthoupoli – Eliniko
- Line 3 (blue line): Airport – Douk. Plakentias – Aghia Marina

The Suburban Railway, or "Proastiakos," is part of the national railway network of Greece.

Athens Suburban Railway has 4 lines:

- (Magenta) Suburban Line: Athens International Airport – Koropi -Ano Liosia
- (Yellow) Suburban Line: Piraeus – Athens – Athens International Airport «Elefterios Venizelos»
- (Blue) Suburban Line: Piraeus – Athens – Kiato
- (Black) Suburban Line: Athens – Chalkida – Athens

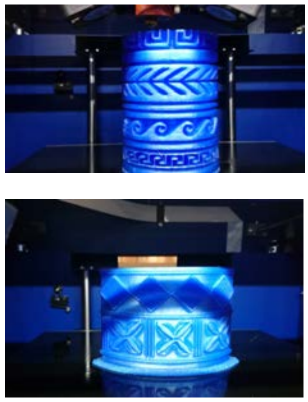
In order to create the 3 Athens Metro lines and the 4 Suburban lines they designed tiles with Braille labels. About 26 tiles with an average 3D-printing time of 19 hours each. They will be placed on Plexiglas and will be offered to the **Lighthouse for the Blind of Greece**.

The Braille labels were created with **TouchSee**, and you can find the **Athens Transport Map** online. Using FreeCAD 0.16, they also designed and 3D-printed the logo of the Athens Metro company "Attiko Metro" and the Athens Suburban Railway company "TrainOSE" with Braille labels.

3. Getting in touch with ancient Greek Culture

When students visited the **Tactile Museum of Athens** for the first time, it was explained to them how difficult is it is to make blind or visually impaired people, "see" the geometric patterns on an ancient vessel. So it was desided that designing the patterns and 3d-printing them **would allow these people "feel" the pottery art of that period**. The vases were from the Tactile Museum of Athens. The geometric patterns (concentric circles, meanders, rhombuses and zigzag lines) on the surface of the vessels in ancient Geometric period.

The sketches were created using **Microsoft Paint.** The software used for the 3d models was **Lithophane** with the appropriate settings. More information about Lithophane can be found on the **Instructables website**.



Printing pottery art

Students also designed and 3D printed other Greek artifacts;

a) The Phaistos Disc from the Minoan palace on the island of Crete

It originates from the Minoan palace on the island of Crete. It is about 15 cm in diameter and covered on both sides with a spiral of stamped symbols. Dating from the Minoan Bronze Age (second millennium B.C.), it´s purpose and meaning remain disputed making it one of the most famous mysteries of archaeology. This unique object is now on display at the archaeological museum of Heraklion in Crete. The 3D printed side is side-b. The students used Lithophane to create the 3D model.

The Phaistos Disc

b)The rock of Acropolis with Parthenon in Athens, Greece

This was the first trial 3D-print. The students used Lithophane to create this model as well.

Apollo's lyre

Apollo's lyre signifies that Apollo was the god of music in ancient Greek myths. The ancient Greek believed that Apollo's lyre had the power to turn things, stones for example, into musical instruments. The software used for the design of the 3D Model was Freecad 0.16.

Apollo's Lyre

4. The floor plans of the Tactile Museum in Athens

Floor plans of the ground and 1st floors of the Tactile Museum were designed in FreeCAD 0.16. There is a base with braille labels for each one of them (consisting of four tiles 18x20 cm) and a memo with braille labels (consisting of two tiles 18x20 cm).

The problem the students faced after designing the floor plan of the ground floor was its size. They could export it as a stl file but it didn't fit the dimensions of their 3D-printer, so they had to find a way to divide the stl file into several pieces. After checking many different options, they installed Solidworks (free educational version) and Autodesk Netfabb Standard 2018 (also free).

Video:
Cut solid design/ shape into different pieces using FreeCAD (YouTube video in English).

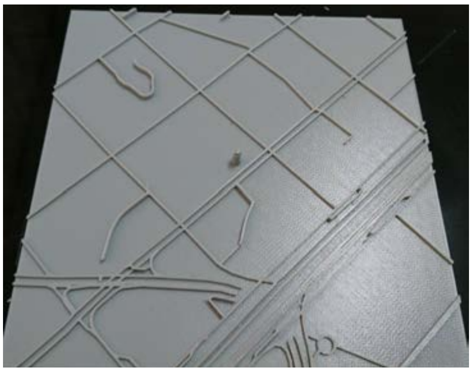
YouTube videos:

- **How to cut a solid shape**
- **How to cut/split an STL mesh into multiple parts by a plane**
- **Split Parts to Fit into 3D Printer** (Solidworks)
- **How to cut stl files for 3d printing FOR FREE** (Nettfab)
- **How to Split Objects In Tinkercad!**

The easiest way was to use Netfabb. From the menu bar, you can choose *File → Split large stl file…* and you get a window where you can choose in how many pieces you want to split your file into, and "Create decomposition". It automatically creates the number of smaller .stl files you asked for.

5. The neighbourhood of Kallithea (the area of the Tactile Museum of Athens)

At the beginning we found the article "**How to print maps, terrains and landscapes on a 3D printer**" on Prusa Printers' website and we decided to use **Cadmapper,** which is a free tool but only for areas up to 1 km^2. The problem was that you couldn't get the streets *without* the buildings and the blind people at the Lighthouse of Greece found it too difficult to follow, as the area of Kallithea is a densely populated area. So the group came to the conclusion that on a tactile map you have to simplify things and get rid of any unnecessary information.



So the group went with **Touch Mapper** ("Tactile maps made easily") which helps users hide the buildings without affecting the map preview. In addtion, the website gives you the possibility to print parts of a multipart map and then put them together to create the map of a big area.

The area around the Tactile Museum of Athens was printed, with the main points of interest (10 buildings) and bus or metro stations, to assist the blind or visually impaired people. Several tiles (18x18 cm) were printed, all tiles of the area, along with the memo tiles, were placed on Plexiglas and donated to the Tactile Museum of Athens.

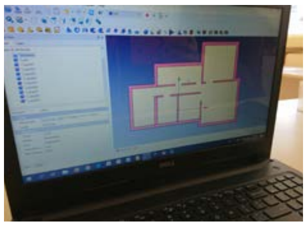
6. The logo of the program and the logo of our school

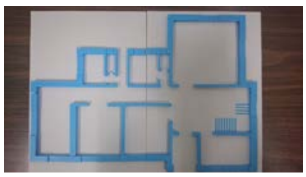
For this project the group used the Lithophane software.

7. Turning a 2D image or logo into a 3D model

Lifewire offers instructions (with pictures) on **how to turn a 2D image into a 3D model,** and the group used the free software **Inkscape** and an on-line converter (through **Online-converter.com** or **Convertio.co**) to convert a .jpg-image into an .svg-file. A **tutorial on FreeCAD Forum** showed how to import an .svg-file and convert it to sketch, which could then be extruded to a 3d model.

The Printer that the students used was Craftbot+, and the software was Craftware for the slicing of the designed models (in order to turn the .stl-files to code).



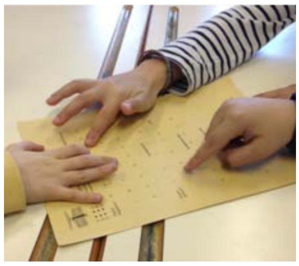


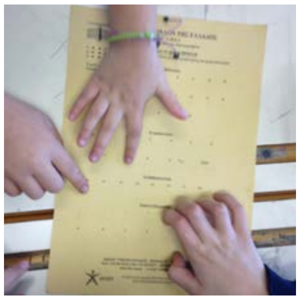
Ellinoaggliki Agogi

Location: Marousi, Greece
Age of students: 7-8 year old and 11-12 years old
Software/websites used: FreeCAD, Inkscape, Craftware 1.21.1, online converter (**Convertio.co**)., Touch-mapper.org, Vectary.com. Touchsee.me, Touchterrain.geol.iastete.edu, Craftware 1.21.1.

ΕΛΛΗΝΟΑΓΓΛΙΚΗ ΑΓΩΓΗ

Focus shifted depending on age groups, skills and interests in order to include all grades, from Pre-K to 6th grade. As schools are an integral part of a community, the aim was to promote awareness focusing on visually impaired people but also to use hands-on educational techniques to promote different kinds of intelligence, bring forth students' talents which may lie beyond the traditional classroom and build solidarity within their small community.

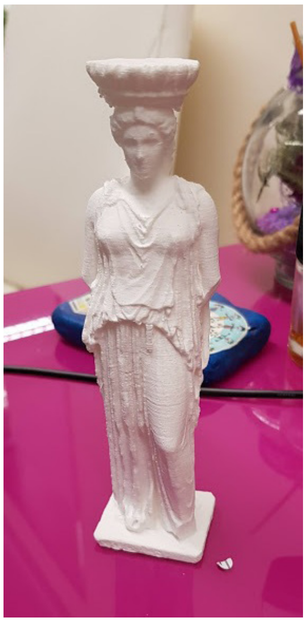




Students reading braille.

1. **Senses of touch and taste:** In Kindergarten, the students explored the senses of touch and taste through games. Having their eyes closed they had to recognize items and taste food.
2. **"The guessing game. Who is it?":** In 1st grade, the students played a game called "The guessing game. Who is it?", in which they had to touch and recognize their classmates having their eyes closed.
3. **"The three little pigs"**: In 2nd grade, the students created a sensory version of the famous fairytale "The three little pigs", using all kind of materials related to the story. As a result, a student with visual impairment could read the fairytale using the sense of touch.
4. **3D road signs:** In 3rd grade, the students created 3D road signs using plasticine.
5. **Louis Braille and the Braille Alphabet:** Also, in 3rd grade, the students did an assignment about Louis Braille and the Braille Alphabet. They tried to recognize some words in Braille, and they had the experience of tactile reading.
6. **Visual impairment:** In 4th, 5th and 6th grade the teachers talked to the students about research, about ideas and the students mentioned famous blind people that they know about like Ray Charles, Stevie Wonder, Louis Braille, etc.
7. **Anatomy of the eye:** In 6th grade, students learned about the anatomy of the eye in Biology class. They also learned about the Tactile Museum in Athens in the English class.
8. **Teacher met a blind woman:** During an excursion, students of 6th grade along with their teacher met a blind woman. The teacher asked the children to observe her as she walked along the pavement. They saw her trying to navigate a store that was covered by a labyrinth made by refrigerators and newspaper stands. Back to the class, the teacher and students discussed the difficulties the woman faced while walking on the pavement.
9. **Listening and locating sounds:** It can be difficult to locate sound while we have no visual connection to our environment. Students would call their classmate that had their eyes covered from different angles and positions inside the classroom and the student would have to turn towards that side. Another group performed the same activity, but they used whistles that they printed out of the 3D printer. The whistles were available as open-source 3D design on the web.

10. **"Explore the environment – explore the small and big spaces"**: Students were divided into groups of two individuals, one wearing a blindfold and the other one guiding his classmate. Through the activity, the students had to walk in pairs around the classroom. First one pair got up and started walking around the classroom. Then more pairs were standing up to walk and the guide-students had to pay attention in order not to make them crash into objects or other students. All the students got excited as they are not used to prevent themselves from using one of their senses. At the end of the activity, the teacher talked to the students about their experience, and they expressed how they felt and how it would have been if we had to walk like this in outdoor spaces; protected, like the schoolyard and public, like the streets. The activity was very interesting, and the students really enjoyed it. All groups changed roles.
11. **Reading Braille:** Following these activities, it was time for the kids to be introduced to the language of the blind. The braille alphabet paper copy made by the "Lighthouse for the blind of Greece" was extremely useful as a tool. All the students had the chance to try it themselves and experience how tactile reading is. In order for them to remember the activity and keep it their memory, the teacher suggested that they try to create a few words in braille at home with their parents using plasticine or round objects.



One of Erechthion's caryatids.

Introduction to 3D Printing

In order to make the first steps with this new technology and get familiar with 3D printing, the students started working based on the transformation of 2D images into 3D objects. They searched the internet for open source 3D designs and printed them.

The following activities were implemented:

1. **Fairytale "The elephant and the ant"** with 3D printed characters: Students of high grades transformed two images – an elephant and an ant – into 3D objects and printed them in order for students of lower grades to use them to tell the story of "the elephant and the ant", as an effort for collaboration across grades.
2. **The school logo key chain**: A keychain was also created in FreeCAD, based on the school logo. In the annual Bazaar of the school, the 3D printer was presented, as a part of their efforts for dissemination, and a lot of key chains were sold for charity purposes.
3. **Printing open source objects:** The internet offers a variety of open source designs to be printed. The most characteristic open source objects that were printed had to do with ancient Athens, following the school visit to the Acropolis of Athens. These were the Parthenon, the Odeon of Herodus Atticus and the Caryatid.

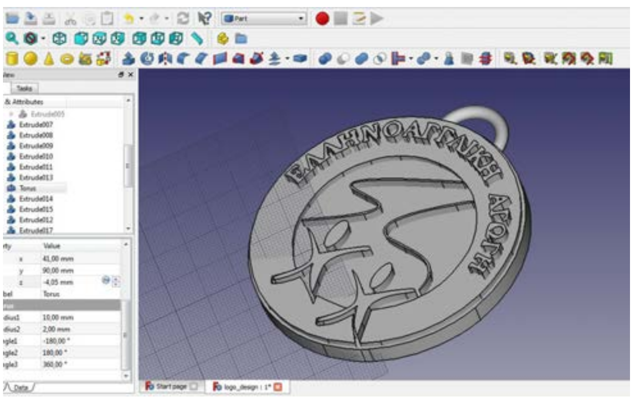
Service Learning & 3D Printing: Final Outcomes

In order to reach the project's main objective, which was the combination of Service Learning and 3D Printing for individuals with visual impairment, we implemented the following outcomes:

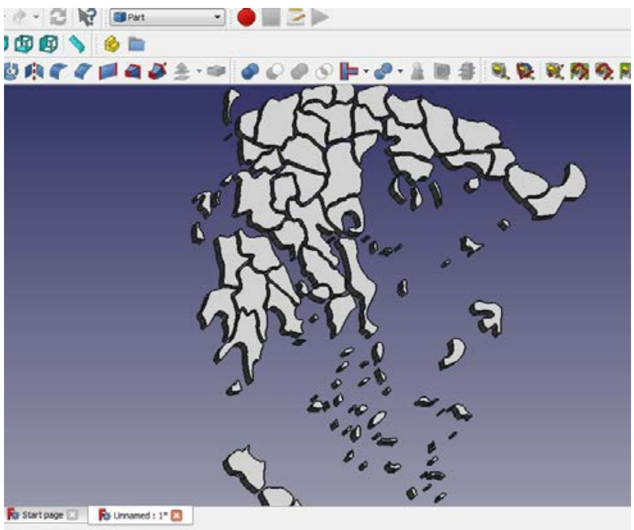
1. **Tactile Map of the Olympic Stadium of Athens and the surrounding area:** As the school is located in the area of the Olympic Stadium of Athens, students and teachers decided to create a tactile map of this area of interest, including the school and the closest train station. We used the website touch-mapper.

org, which takes an area on the map and creates the tactile version of it. However, the job was not that simple since the whole area with the Olympic facilities, the multiple roads, the buildings, etc. is too complicated and the tactile map produced was loaded with unnecessary information, which had to be removed. For this purpose, the website vectary.com was used to edit the map, removing unimportant roads and buildings. This editing took a significant amount of time. Finally, the students colored the most important points on the map, and they were satisfied with the result.

2. **Tactile Map of the Acropolis:** The next idea we had was to create a tactile map of the Acropolis Rock, including the main monuments preserved until nowadays. We used FreeCAD to design the rock. Additionally, we used a plan of the Acropolis as a guide in order to be precise about the location. Finally, we created the legend of the map in Braille, using the website touchsee.me.
3. **Islands of the Mediterranean:** Using the website touchterrain.geol.iastate.edu (which creates the 3D terrain of a selected area, according to the appropriate parameters selected by the user) students were able to do a project about the the islands of the Mediterranean. Each item on the base is detachable for the audience's convenience.
4. **The Caryatids:** As mentioned, the web can be a great source of free 3D designs to be printed. Instead of printing separate or irrelevant objects, the class thought of a project showing the famous Caryatids of the Erechtheum exactly as they are exhibited by the Acropolis Museum. One of them is missing – and so it was printed separately – as it is located in the British Museum. The 3D printed Caryatids are also detachable.
5. **Outline of Europe:** Our school's participation in a European Erasmus+ program gave the idea to the students to print a map, showing the outline of Europe, with small gaps between countries in order to be distinguished. This outcome was based on a 2D image transformed into a 3D map using convertio.co (to convert the jpg image into svg format) and FreeCAD.



The keyring

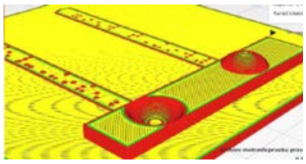


Map of Greece

I.E.S. Benlliure

Location: Valencia, Spain
Age of students: 15-16 years
Duration: 3 hours a week, one semester.
Software/websites used: FreeCad, TouchSee

A group of 15 students divided into different groups participated in the "Design and 3D printing" course. This was an optional subject, called "Design and 3D printing." During their lessons the students went with their teacher to visit the model of Valencia Cathedral, using a blindfold they all felt the model of the cathedral with their hands. They hosted a braille workshop and participated in a goalball match. In the class the students learned how to use the software FreeCAD, through exercises proposed in class. They designed a plan for the project, printing out tests to detect errors and finally printing the final plan.



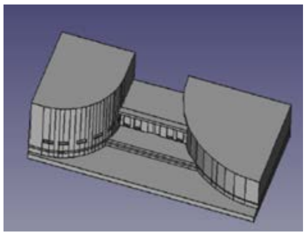
3D printing projects

Floor plans: One group of students created a scaled-down model of their high school. Based on real plans, they made the different parts to scale and divided into separate pieces for them to fit the printer. The separate pieces were glued together afterwards.

Another group designed floor plans for the central area of their school. The plans were distributed in different parts so that they comply with the regulations to be accessible for visually impaired students. Symbols and signs had different colours to be better distinguished.

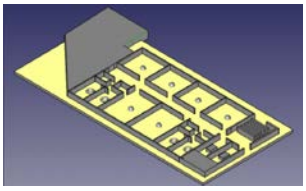
Metro Valencia

Metro lines: One group designed a map or list of the Valencia metro lines. Initially, the design had both larger and smaller circles but as it turned out, blind people did not distinguish them, so the shapes were changed. Each metro line had a different colour and stops were represented by a half sphere and transfers as an inverted half sphere. Different pieces were then joined together so that the vertical line was completed. Since braille must be printed sideways (or slanted), the dimensions of the pieces are limited to the height of the printer.



Institut Benlliure

Signs: Another group of students designed signs for the common areas of the school centre; cafeteria, library, assembly hall, secretary, etc. The signs were to have contrasting colours, and the students chose yellow and black as their fellow students with visual impairment found them better to see. Below was the name repeated in braille. The letters and the base were designed using FreeCAD, and then braille was added. Braille for 3D printing can be created using TouchSee website and downloaded as an .stl- file, to be added (or imported) to the original design. In addition, one student designed signs for the WCs. In the beginning the standard forms indicating WC for boys and girls were selected, but later the figures were changed so that people with different types of visual impairments could recognize them.



Floorplan

I.E.S. Conselleria, Valencia, Spain

Location: Valencia, Spain
Age of students: 15-17 years
Software/websites used: Tinkercad, TouchSee, Libreoffice

The objective was to design and print a tactile version of the 9 lines of Valencia's metro system (**metro Valencia**). This implementation is developed with students of 1st course of a basic vocational training program in IT (level 1 of the European Qualification Program). The students, eighteen in total, all have a history of difficulties at school, and some have a serious problem with reading comprehension as well. The majority of the group has no study habits and have a low motivation on the subjects of the curriculum.

The course's main objective was to design and print a tactile version of the 9 lines of Valencia's metro system (LINK). Currently, no version is available for non-sighted people. These students used Tinkercad for their designs.

This objective can be divided in the following secondary objectives:

- Configure and use a 3D printer
- Use a 3D design software for problem solving creations
- Gain awareness with the non-sighted people

The idea is to implement an easy and versatile way to design and create the metro plans. For that reason, all the elements are going to be designed and printed separately and finally glued to a cardboard.

In the first place, a series of introduction activities are developed by the students in order to acquaint experience with the tools that are going to be used. Then, the 18 students were organized in 9 groups of two components, and each group was assigned a different line.

Each group had to design 4 .stl documents:

- **Line Stops:** A consistent design with the stops of the line assigned. The stops with transfer must have a different design than a regular one. Each stop has to have information regarding the zone that it belongs (each zone has a different fare).
- **A design contest** is promoted on order to choose the best way of representing a metro stop, according to the requirements.
- **Stops' names:** The names in Spanish braille of all the stops (using touchsee.me)
- **Line logo:** A label with the logo of Metro Valencia and the name of the line in written text and in braille.
- **Transfers:** Small labels with the number of the line to indicate transfers. Each group has to deliver the transfer label of their own line to the other groups.

Once the designs are made and revised, they must 3D print them in the representative color of the line. Finally, they glue all the elements in the cardboard. Every student, also, must design a general plan with all the lines together, in a tactile version of the regular line plan. The idea is giving them something to work on while the components are being printed.

Planification and schedule. The sequence of activities is the following:

1. Design a tab for a table game (individual task) - 3h
2. Design a table label with your name in it (individual task) - 3h
3. Design a 2D logo with LO Draw (individual task) - 5h
4. Design a keychain with the logo (individual task) - 1h
5. METRO PROJECT: Design contest: tactile metro stop (group task) - 3h
6. METRO PROJECT: Design the parts of your metro line (group task) - 9h
7. METRO PROJECT: Convert the general metro plan in 2D to 3D (individual task) - 3h
8. METRO PROJECT: Print and mount your metro line (group task) -3h

Total hours: 30h (10 lective sessions).

Appendix I

Glossary

- Pupil – in front of the eye, responsible for adjusting the quantity of the light passes into the eye.
- Iris – circular structure of the eye, responsible for controlling the diameter and size of the pupil. The colour of the eye is defined by the iris.
- The lens is behind the pupil and is responsible for directing light to the retina at the back of the eye. Retina – situated in the back of the eye is responsible for converting light into pictures that are then forwarded to the brain. The retina has two main cells which responds to light:
- the cones, mostly in the centre of retina responsible for sharp vision, seeing in light condition and discrimination of colours
- the rods at the periphery of the retina responsible for
- The macula is a tiny dot in the middle of the retina. It is responsible for enabling us to see things clearly.
- Optic nerve – in the back of the eye, exist of the retina seeing in dim light and discrimination of movement
- Visual pursuit – ability to follow an object's movement
- Accommodation – ability to change the focus from near to far away, and vice versa.
- Visual acuity – ability to recognise fine details and see sharply.
- Visual field – the entire area that can be seen with the both eyes when the eyes are directed forward. The binocular visual field is around 120 degree, the monocular is 90 degree from the middle to the sides and limited by the nose and the vertical field is extended to 60 degree above and 70 degree below.
- Visual adaptation – temporary change in sensitivity or perception when exposed to a new or intense stimulus
- Depth perception – the results from the brain´s interpretation of the slight difference between the disparate pictures of the same visual scene provided by the two eyes
- Colour vision – colour vision is possible due to photoreceptors in the retina of the eye known as cones. These cones have light-sensitive pigments that enable us to recognize colour.
- Motion perception – ability to see movements controlled by the centre of the brain
- Strabismus is a condition in which the eyes do not properly align with each other when looking at an object.

The quality standards of service-learning are (Stark et al., 2016):

- The service component meets a real civic need.
- Service Learning is meaningful and relevant to community partners and students.
- It explores issues that are vital to social, civic, cultural, economic and political society.
- The community partners have been consulted.
- Community organizations are valued as partners.
- There is a flow of knowledge, information and benefits in both directions between the University and its community partners in activities.
- Every individual, organization, and entity involved in the service-learning functions as both a teacher and a student.
- Defined goals are reachable and measurable, for the specific service-learning project.
- Goals and values are discussed with the community partner.
- Service Learning is linked to the curriculum/study program of students.
- Teachers/academic staff are actively involved.
- Service Learning is integrated in the study program in a systematic way.
- Service Learning has credit recognition.
- Civic learning relied to personal and social competencies, is an important category of students learning goals (beside academic learning goals).
- Academic theory is viewed in a real-world context.
- Service Learning offers opportunities to learn and deepen understanding for all participants (students, faculty and community partners).
- Students have a strong voice in planning, implementing and evaluating the service-learning experience

- Service-learning facilitates active, regular and ongoing student.
- Reflection is guided by teaching personnel.
- Reflection is guided by community partners.
- Reflection leads to understand diverse perspectives of challenges.
- There is a mechanism that encourages students to link their service experience to the academic curriculum.
- There is a mechanism that encourages students to reflect upon the effects of the service.
- Support and coaching for students from academic staff is ensured.
- Support and coaching for students from community partners is ensured.
- Service Learning offers adequate time frames for making experiences effective and sustainable.
- Service Learning offers adequate time frames for learning in community settings/with community partners.
- Evaluation is included as an integral part of the service-learning activity.
- Documentation is included as an integral part of the service-learning activity.
- Service work is presented to the public.
- Service-learning makes an opportunity for the community to enter into a public dialogue.
- The service-learning activity is transdisciplinary.
- It is expected that the activity will have an impact in the community after its closing.
- The Project has the resources to continue running in the future.
- The community is engaged in sustaining the program for the long-term. All the requirements may not be fully achieved in all Service learning, but the quality standards can serve as a guideline of indicators when one is about to design or to evaluate service-learning activities.

Appendix II

Video links

Introduction to 3D printing
Video no. 9, on 3D-printers 9
First steps on FreeCad. Volumes. Translation
Boolean operations with volumes (union, subtraction, intersection) Help with Overview:
FreeCad. Boolean Operations
Example: Designing a building
Arrays and repetition of objetcs
Designing with sketches
Printing with Witbox 2
Maps with sketches
Drawing maps based on paths
Creating 2D sketchs with InkScape
Plans with Texts and Objects
Copying a 2D Map with Inkscape
Utilizing 3D Printing to Assist the Blind
Research: Proposal for SVG2DOT: An Interoperable Tactile Graphics Creation System Using SVG outputs from Inkscape :
Tinkercad is a free online software (no download required), and very user friendly.
FreeCAD is another popular open source program. It requires downloading, but is available for many operating systems, including Windows, Ubuntu, Mac OSX, Fedora, and seems to run on a number of Linux-systems as well.
Touch-mapper.org: A map-generator
Cadmapper.com - Instant CAD files for any location on earth - free areas up to 1 km^2.

Additional material and references

Spain's official tourst portal
SPSM: 3D-skrivarnas möjligheter och begränsningar
Comparison of free CAD software programs for 3D printing (May 2018)
Top 25 of the best free CAD software (Oct. 2018)

Appendix III

3D printing FreeCad: Making dice step by step.

1. File – *New*.
2. Go to *Start* on the top of the tool bar and select *Part* to create items.
3. Select *Create a cube* that is a picture of a yellow dice on the top of the toolbar.
4. You can change the perspective of the cube high on the toolbar by selecting one of the green dice, for example axonometric view.
5. You can right-click on the background and select *Navigation styles* and select *Blender* then you can rotate the cube on all sides without changing the real size.
6. Under the *Labels & Attributes* to the left, are the things we have already designed. We already have a cube design. When *Cube* is pressed the dice lights up, and to the left and below the dice shows the cube's properties. There you can set and change the dice properties.
7. At the bottom left corner is: *View* and *Data*. View displays visualization, color and lines. In Data you can change the shape of the dice.
8. The next step is to add another form to the dice. Then we choose one form of the yellow shapes near the top of the bar.
9. Choose the *cylinder*. Then add a cylinder to the left of *Labels & Attributes* below the Cube. You can change the name of the items by right-clicking the items in *Labels & Attributes* and selecting *Rename*.
10. The shape of the cylinder can be changed in *Data*, the option is to select the degrees of the circle in the Angle.
11. You can change the position of the cylinder on the cube by selecting the *Data-Placement Position* and pressing the arrow. Then you can change the numbers on the x, y or z axes.
12. You can change the angle of the object by selecting the green dice on the toolbar near the top. For example, if you set to *top view*, you can see how the item looks from above. You can see all the sides of the object.

Appendix IV

Tutorials (videos) and additional information

Tinkercad's beginner's tutorial – more detailed than the website's tutorial/ exercises. Good for getting familiar with the basics.
Making organic shapes on Tinkercad.
Scan a drawing, convert to .svg-file, and import into Tinkercad.

FreeCAD:
Learn FreeCAD by Elwirak (YouTube channel)
The part design workbench (55 min.)
A crash course (18:49 min.) in the design of a part in FreeCAD and printing it on a personal 3D printer.

Other:
Fusion 360 tutorial for absolute beginners (part 1)

Choosing the right software:

According to G2crowd, these were the best free and open source CAD tools in 2018:
1. FreeCAD
2. Fusion 360
3. Onshape
4. nanoCAD
5. OpenSCAD
6. Tinkercad
7. 3D Slash
8. LibreCAD
9. DraftSight
10. QCAD
Their review includes a short description, pricing, and features for each program.

- **Additional comparison, reviews**, and more.
- **Comparison of free CAD software programs** for 3D printing (May 2018)
- **Top 25 of the best free CAD software** (Oct. 2018)

To generate braille, the **TouchSee-website** can be very useful. The website allows people to write text and convert into braille, and save as an .stl-file which can then be added to a 3D-file created in Tinkercad or FreeCAD. When adding written information in braille, keep in mind that the text may take up more space than expected, especially compared to written text intended for
the sighted, which can be scaled down to be relatively small.

Interesting articles and material:

- **4 ways 3d printing is helping the visually impaired "see" the world.**
- **10 ways 3D printing supports the blind**
- **MyMiniFactory** – over 60,000 free and paid 3D printable objects

The Art of 3D Print Failure is a website which is pooling pictures of 3D-printing gone wrong, often with amusing results.

Standards for raised diagrams: https://www.access-board.gov/guidelines-and-standards/buildings-and-sites/about-the-ada-standards/ada-standards/chapter-7-communication-elements-and-features

"Advisory 703.2 Raised Characters. Signs that are designed to be read by touch should not have sharp or abrasive edges.

703.2.1 Depth. Raised characters shall be 1/32 inch (0.8 mm) minimum above their background."

703.3 Braille.

Braille dots shall have a domed or rounded shape and shall comply with Table 703.3.1.