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State of the Art
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Disability And Professional Empowerment Engaging 3d Printing

(KA220-VET - Cooperation partnerships in vocational education and training)

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Introduction

In the current social context characterized by the global aging of the population, the number of disabled people is set to increase. According to the survey on health and social inclusion in Europe (Eurostat 2016), there are 70 million people with disabilities over the age of 15.

At European level, by 2020 it is expected that one fifth of the population will have some form of disability.

The EU and all its Member States are contracting parties to the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD). For the EU, this treaty inspired the content of the European Disability Strategy 2021-2030.

Within this social framework, a change of logic in taking care of the disabled is fundamental, which is no longer purely "welfare", but which is oriented towards the development of autonomy, social inclusion and prevention of forms of of marginalization.

The DEEP project starts from the assumption that in order to face these social changes and the challenges that derive from them, it is crucial an innovative training that is able to bring together professionals belonging to different professional categories (health professionals, occupational therapists and experts in the 3D printer sector), overcoming the current logic that disability is a topic limited to specific sectors and embracing the broad vision that touches all areas of society.

This training model will aim to bring the socio-health world closer to the potential of using 3D prints in the world of disability and to increase motivational and pro-social skills in target professionals, essential for relating to people with disabilities.

In order to achieve this training model, the DEEP partnership started with the creation of the State of the Art, considered a first intellectual milestone and achieved thanks to the contribution and expertise of each partner.

In producing this report, we started from the transfer and adaptation of the best practices that partner countries have already effectively tested within their context and from a comparative analysis of the best intervention practices currently adopted in the European context.

In particular, the research was carried out through: an assessment of the state of the art of technological development in the disability sector; a collection of existing training materials on the subject of disability and 3D printers; a search for intervention programs that are more effective in relation to the topic dealt with. Recent studies show that in rehabilitation, educational and professional interventions, the technologies currently available can help the rehabilitation, autonomy, school, work and social integration of people with all types of disabilities, ages and disabling diseases. Specifically, in the world of 3d printing, the potential of technology emerges above all when it is the disabled themselves who are co-designers of their aids: it is therefore crucial to also consider their needs in the realization of these aids through 3D printing, as by various

studies show that up to one third of the aids are not used by the disabled (Scherer 2002, Federici and Borsci 2014) for various reasons: personal factors (age, sex, performance expectations, change in self-image, type of disability), characteristics of the aid (quality, functions, aesthetics) (Wessels et al. 2003). Taking charge of the person with disabilities, as a whole, needs a series of skills that make a holistic approach necessary. The goal of this research is to understand how to create innovative training experiences that aim to bring the world of disability closer to that of 3D printing.

1. What does disability mean?

To better understand the worldwide impact of disability we must consider that over 1 billion people, about 15% of the population, have some form of disability, and at least 1/5 of these people, about 110-190 million, face "very significant" difficulties in their daily lives. In addition, about 80% of people with disabilities live in developing countries, where 1/3 of school-age children have a disability. In the EU, the percentage of people with disabilities is at least 50 million (10.8%) (World Report On Disability, WHO, 2011).
We must also consider that due to the aging population, disability rates are increasing. A bidirectional link between poverty and disability has been found. The onset of disability and increasing severity of disability lead to worsening social and economic well-being with a negative impact on education, employment, and earnings. In addition, because of higher costs, people with disabilities and their families are poorer than others for the same income. This is evidenced by Eurostat data on disability in the European Union (2011) according to which the employment rate of people with disabilities is 44% (compared to 75% of people without disabilities), people with disabilities are 70% poorer than the average, between 20% and 40% of people with disabilities do not have sufficient help in daily activities. People with disabilities in Italy are 5.2%, about 3.1 million people, of which: about 1.5 million over 75, about 284000 students with disabilities, 27% live alone while 61% live in families (ISTAT, 2017).
The main difficulties encountered by people with disabilities include: discrimination, lack of health care, lack of rehabilitation and architectural barriers (inaccessible public transport, buildings and information technology). This leads to consequences such as poorer health, limited training and employment opportunities, poverty and lower educational attainment.
It is important to keep in mind that disabilities can also be due to mental disorders (about 10% of the population, WHO, 2017), but it is more difficult to detect disabilities related to mental illnesses than physical illnesses due to the presence of cultural biases that lead people with disabilities or their family members to not have contact with relevant public services, or to not respond appropriately to statistical surveys.

1.1 Historical-social evolution of the construct

The concept of disability has evolved over a long period of time, both socially, culturally and historically.

Since ancient times, disability has been considered a problem, a defect. In the Greek-Roman age, the dominant values reflected the ideal of kalos kai agathos (beautiful and good), strength and beauty were considered ideals to be achieved, while deformity and disease were not tolerated because they were associated with guilt and divine will. Any physical imperfection was in fact associated with evil and interpreted in a moral and / or religious way as a punishment. People with disabilities were seen as scapegoats to be blamed for destructive natural events, or the faults of the community.

During the spread of Old Testament Christianity, disability continued to be viewed as a punishment. The child with disability was due to the sin committed by the mother. While in the New Testament there is a profound cultural change with the birth of a new conception of disability: the person with a disability is considered as part of the community. The disability of the individual is no longer interpreted as a consequence of sin, but is read as a warning to all the faithful to do good works. Jesus, in this sense, invites the community to exercise charity towards the needy, whether they are poor, sick or crippled, denouncing all forms of inequality. Despite this period of apparent inclusion, from the thirteenth century onwards, people with disabilities were relegated to the primitive hospital structures run by monastic communities and the Church. In London, the hospital of St. Mary Bethlehem, known to history as Bed-lem, represents one of the first asylums, famous for the brutal and inhuman treatment reserved for patients. Similar facilities were also created in Paris, where the physically and mentally disabled were confined in the two most famous hospitals in France: Salpêtrière and Bicêtre (Pesci & Pesci, 2005). Starting in the early nineteenth century, particularly with the industrial revolution, we see another important change. In those years, a new dominant social class, the bourgeoisie, begins to emerge with its values and ideals of productivity and efficiency. The philosophy of this new social class started from a re-reading of Darwinian evolutionary theory applied to society or "Social Darwinism". At the basis of this ideology is the concept of natural selection, that is, survival of the fittest and the relative marginalization of those who are not "fit", marking a further social exclusion of disabled people. For all those who do not participate in productive life, because they are abnormal or deviant, institutionalization was the generalized response; thus orphanages, asylums, hospitals and prisons spread. The classification systems and the technicians responsible for their application, take on an increasingly fundamental role, favouring the development of a new social representation of the disabled: that of the "sick", a person in need of care, assistance and special education (Lepri, 2011).

Darwin's ideas were in fact used in a completely instrumental way to support a wide variety of social and political opinions, which led to inevitable hostility between nations and races, attributing scientific validity to totalitarian ideologies.

In fact, the English anthropologist Francis Galton (1822-1921), in his work Hereditary Genius (1869), introduced the term "eugenics" to define the study of the conditions in which superior men are "produced". In England it initially spread under the name of "lineage culture", and then expanded to the United States, Sweden, Germany, France and Italy. Eugenics developed as a response to the fear of the time that natural selection had ceased to act for the betterment of the species and that therefore man should take the reins of evolution into his own hands. The purpose of eugenics then became to rid humanity of disease and imperfection by encouraging the reproduction of the best individuals and discouraging that of individuals with some form of physical and mental disability (Brambilla, 2009).

Italian scientists were also influenced by the eugenics current from the 20th century, its expression culminating with the advent of fascism. With his "ascension speech" in 1927, Mussolini affirmed that the state is the main guarantor of public health and that its task is to cure the race of impurities and imperfections. During the twenty-year Fascist period, eugenic control took the form of legislative measures and drastic increases in the number of patients admitted to psychiatric hospitals. Fascist physicians and psychiatrists were obsessed with the alleged spread of mental degenerations and infirmities, so that between 1926 and 1928 more than fifty thousand mentally ill patients were interned (Padovan, 2003).

Similarly in Germany, the German National Socialists, in the thirties of the twentieth century, adopted the most radical and violent measures of forced sterilization. The tragic history of the Nazi holocaust begins with the systematic elimination of the weakest and most defenceless human beings. The objective was to eliminate disability by resorting to various methods: sterilization of adults, euthanasia of children, work in concentration camps. The lives of people with disabilities were considered lives unworthy of being lived. To make the German population aware of the necessity of euthanasia, Nazi propaganda began to denounce the high costs that the treatment of disabled people entailed for the community, thus justifying the elimination of all those worthless human lives that represented a burden on society (Friedlander, 1997; Tarditi, 2007).

Subsequently, Franco Basaglia, an Italian psychiatrist and neurologist, based on the collection of essays Asylums (Goffman, 1961) began in Gorizia an experience that represents the first Italian attempt to propose an alternative to a reality that he tenaciously rejected: the asylum. Basaglia intended to break down the barriers between what happened inside the asylum and the world outside, "producing through this rupture a transformation of the relationship between healthy and sick, which simultaneously challenges the definition of health and disease as an instrument of discrimination, in a social context based on the division of class and labor" (Basaglia, 1968). Basaglia is the promoter of a reform that does not end within the asylum institution but expands its boundaries to the whole society. Only when the problem of the mentally ill will be addressed by society, therapeutic facilities centered on the needs of a free subject and not an object placed under custody will be set up. In 1978, Law 180 was passed, the so-called Basaglia law on "Voluntary and Compulsory Health Care Assessments and Treatment", through which asylums were closed and the institution of forced hospitalization in psychiatry was regulated. The passing of this law marks a turning point in the road to the integration of disabled people, often assimilated to the mentally ill, gaining wide support in Italy and abroad. To all intents and purposes, it represents a historic watershed between a before and an after in Italian psychiatry.

The World Health Organization (WHO), in 1980 defined disability in the "International Classification of Impairments, Disabilities and Existential Disadvantages", distinguishing three levels:

- Impairment: any permanent loss or abnormality to an anatomical structure or psychological, physiological, or anatomical function (externalization);
- Disability: any limitation or loss (resulting from impairment) of the ability to perform a basic activity (such as walking, eating, working) in the manner or extent considered normal for a human being (objectification);
- Handicap: the condition of disadvantage, resulting from an impairment or disability, which in a certain subject limits or prevents the fulfilment of a social role considered normal in relation to age, gender, socio-cultural context of the person (socialization).

Impairments, disabilities, and handicaps can limit a person's enactment of the vital roles of orientation, physical independence, employment, social integration, and economic self-sufficiency.

In 1999 the WHO published the new "International Classification of Impairments, Personal Activities (ex-Disability) and Social Participation (ex-Handicap or Existential Disadvantage)" (ICIDH-2). (ICIDH-2), in which two of the three carrier concepts that characterize a morbid process are redefined:

- its exteriorization: impairment
- objectification: no longer disabilities but personal activities
- the social consequences: no longer handicap or disadvantage but different social participation

More specifically:

- personal activities refers to the limitations of nature, duration, and quality that a person suffers in his or her activities, at any level of complexity, due to a structural or functional impairment. Based on this definition, every person is differently abled.
- social participation refers to the restrictions in nature, duration, and quality that a person experiences in all areas or aspects of his or her life (spheres) due to the interaction of impairments, activities, and contextual factors.

In the new WHO Classification, the term "handicap" has been definitively set aside given its confusing and pejorative connotation.

While specifically, the term "disability" means the reduction or loss of an ability to perform an activity considered normal for the context of reference. People with disabilities are defined as those with enduring physical, mental, intellectual or sensory impairments that in interaction with barriers of various kinds can hinder their full and effective participation in society on an equal basis with others (ONU, 2006).

1.2 International Classification Systems on Disability

The evolution of the concept of disability has led to an evolution of its system of classification and evaluation. In fact, the principles of the ICF (International Classification of Functioning) are in line with the most recent idea of integration, i.e. the ICF is proposed as a bio-psycho-social classification model that is decidedly attentive to the interaction between a person's ability to function and the social, cultural and personal context in which they live. The ICF is derived from the 1980 ICIDH classification and complements the ICD-10 classification, which provides information on the diagnosis and etiology of disease. The ICF does not contain references to disease, disability, and handicap, but focuses positively on function, structure, activity, and participation. Specifically, the ICF: describes and measures health and disability in a given population; describes what can occur in conjunction with a given health condition; is applicable to everyone; views disability in relation to a person's contextual and life factors; and describes functioning as a continuum, without categorizing disabilities.
The structure of the ICF includes two parts: Part 1 deals with Functioning and Disability; Part 2 deals with Contextual Factors.

Each part consists of two components:

PART 1: Components of Functioning and Disability

The Body component includes two classifications, one for the functions of body systems (physiological and psychological functions of body systems) and one for body structures (anatomical parts and body functions). Chapters in the two classifications are organized by body systems.

The component of Activity (performance of a task or action by individual) and Participation (involvement in a life situation) encompasses the full range of domains indicating aspects of functioning from both an individual and social perspective.

PART 2: Components of Contextual Factors

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The first component of Contextual Factors is a list of Environmental Factors (attitudes, physical and social environment in which people live). Environmental Factors impact all components of functioning and disability and are organized in an order from the environment closest to the person to the more general environment. Personal Factors (attitudes, personality, education, culture, lifestyles) are also a component of Contextual Factors, but are not classified in the ICF because of the great social and cultural variability associated with them. Any environmental factor can positively modify a person's functioning in a given activity, i.e., be a facilitator, or limit functioning, creating or amplifying a person's disability, such as a physical obstacle, a staircase, stigmatizing attitudes of individuals or groups, the absence of supportive technologies, and act as a barrier.

The assessment of functioning must specify the context of a person's life. It is different to assess an individual's functioning at home or in a ward, in an adapted setting or one with physical or relational barriers to participation, in a familiar or unfamiliar environment. Applying ICD-10 and ICF in a complementary manner can provide a comprehensive picture of the individual's disease and health status functioning.

First ICIDH and then ICF proved unable to describe in detail and accurately the functional profile of developmental individuals because they do not contain categories representing the specific developmental characteristics of children and youth; in particular, some codes related to cognitive function, language, play, learning, and functioning at home, school, and in the community are missing. Therefore, a developmental age-specific classification was developed.

The "International Classification of Functioning, Disability and Health for Children and Youth", now called ICF-CY for short, is the first classification derived directly from the ICF, with which it is fully compatible, covering the age range from birth to eighteen years of life. The final version of this classification was presented for the first time by the WHO in Venice in 2007.

ICF-CY expands the coverage of the ICF through the addition of content and greater detail aimed at capturing the specific body functions and structures, activities, participation, and environments of infants, children, preadolescents, and adolescents.

ICF-CY, like ICF, should be used in a complementary manner to ICD-10.

The reasons for the development of the ICF-CY are based on practical, philosophical, taxonomic, and public health considerations. From a practical standpoint, it was necessary to create a classification that takes into account the changes associated with growth and development; moreover, manifestations of functioning, disability, and health conditions in childhood and adolescence are different in nature, impact, intensity, and consequences from those in adults. From a philosophical point of view, it was essential that a classification, aimed at describing the health and functioning of children and adolescents, be in accordance with international conventions and declarations for the protection of children's rights, so that it could be evidence, support and empirical foundation to ensure the rights of children and adolescents.

In adapting the content of the ICF to the ICF-CY, particular attention was paid to four key issues:

Development is a dynamic process in which the child's functioning depends on ongoing interactions with family or other caregivers in the immediate social environment and cannot be understood by seeing the child in isolation. At this developmental stage, the influence of the family is greater than in adult life.

In children and adolescents, the timing of the appearance of certain bodily functions or structures and the acquisition of certain skills may vary according to individual differences or physical and psychological factors in the environment; thus, it is important to keep in mind that the failure to appear in functions, structures, or skills may not be permanent but reflect a developmental delay.

Participation, defined as "involvement in a life situation," particularly in the young child, is defined by parents, caregivers, or service providers.

The nature and complexity of children's environments change dramatically as they grow; furthermore, considering the position of dependency in which children find themselves during development, the environment has a significant impact on their functioning.

ICF-CY development operations have included:

- Changing or expanding descriptions;
- Assigning new content to unused codes;
- Modification of inclusion and exclusion criteria;
- Expansion of qualifiers to allow for inclusion of child development aspects.

(WHO, 2007)

Another standardized planning and assessment tool used and well-known in Italy is the VADO (Assessment of Abilities and Definition of Objectives). It was developed in the '90s by a group of operators with long experience in the rehabilitation field and researchers experienced in the development of standardized assessment tools, VADO is an innovative tool for the assessment and planning of individualized rehabilitation interventions with people who have personal, relational and social disabilities due to mental distress. Specifically, the purpose of VADO is to define the objectives of an individualized rehabilitation program for people who have difficulty in carrying out activities of daily living, to have a satisfactory relational life and, more generally, to be autonomous and evaluate the progress of the program over time, in terms of objectives and outcomes achieved. The VADO is therefore built on two fundamental components: a first component related to the evaluation of the patient, and a second one related to the planning and conduct of the rehabilitation program. The Functioning Assessment (FEA) interview can be used in whole or in part to gather the necessary information. The components considered in the interview are:

1. Self Care
2. Clothing care
3. Caring for your physical health
4. Taking care of your mental health
5. Home
6. Living area
7. Caring for one's living space and collaborating on domestic activities
8. Productive and/or socially useful activities/study
9. Amount and type of daily activities
10. Movement speed
11. Participation in the life of the residence or day care center
11. Participation in family life
12. Affective life, sexual and sentimental aspects
13. Child care
14. Frequency of "external" social relationships
15. Friendship and helping relationships
16. Aggression control
17. Other rules of coexistence
18. Security
19. Interests
20. General Information
21. Education level
22. Money Management
23. Travel and use of transportation
24. Phone usage
25. Shopping and running errands
26. Facing emergency
27. Income and application for pensions and benefits

But also: current and previous strengths and resources

The results of the assessment are reported synthetically on the Personal and Social Functioning (FPS) scale and, more operationally, on the Rehabilitation Areas (AR) form. The areas of functioning assessed are:

- Care for yourself and the environment
- Family and social relationships
- Work/study and community service activities
- Aggressive or disturbing behaviour

Then to develop the rehabilitation program are defined:

- Overall Goal: To bring the patient to live, work, and experience new things in the environment of his or her choice, as independently as possible given the starting conditions;
- General objective: concerns the area in which it was decided to intervene;
- Specific goals: operationally defined, achievable in a few months.

(Morosini et al., 1998)

Nowadays, in light of the current classification systems, disabilities were categorized as:

- Sensory disabilities: disabilities that affect the senses (sight, hearing, but also touch, taste, smell);

This expression primarily denotes three types of disabilities:

- Blindness or low vision with vision not exceeding 3/10;
- Deafness or hearing loss with hearing loss greater than 25 decibels in both ears;
- deaf blindness characterized by the coexistence of the two sensory disabilities visual and auditory.

Sensory impairment often affects relationships and communication. A visual impairment or dysfunction does not allow a person to fully grasp the non-verbal communication of his or her interlocutor and, in the same way, a hearing impairment or dysfunction does not allow a person to clearly perceive what is being said by another person. But it also affects one’s own independence and everyday life.

- motor disabilities: they concern the motility and efficiency of the organs of the parts of the body deputies to the movement;

The main motor disabilities concern posture, coordination and muscle tone. The disabled person, therefore, is unable to maintain the "tonic dialogue" between the surrounding environment and his or her own ability to move. Some declinations of this type of disability are:

- Infantile cerebral palsy, these motor disabilities affect two children in every thousand, already during the first months of life show difficulties of varying intensity in the movement that can affect one or more limbs, from monoplegia that affects only one limb to tetraplegia that affects all four limbs;
- encephalopathies, which are genetic in nature, manifest as tremors, rhythmic body oscillations, and muscle changes between antagonistic muscles;

- Dysgraphia, the inability to produce good quality writing, is often a disorder that affects the psychological side of the student and requires in-depth analysis of both school and family dynamics;
- motor clumsiness, concerns subjects who present nervous tics, involuntary movements that the subject makes in a situation of great discomfort. Generally do not limit the daily life of the subject, except in some cases where they occur in severe form including Tourette's syndrome which also involves a continuous repetition of sounds such as grunts, barks and sounds due to swallowing.

- Intellectual disabilities: they concern both the intellectual abilities that can be verified through the IQ (IQ: ratio between chronological age and mental age of the subject), and more specific disabilities such as mental deficiencies (M.I.) and specific learning disabilities (e.g. dyslexia, dysgraphia, dyscalculia, etc.);

In DSM-IV-TR, the actual concept of intellectual disability was indicated by the diagnostic category of Mental Retardation, whereas in DSM-5, the term mental retardation was officially replaced by intellectual disability (intellectual developmental disorder). The term intellectual disability is the equivalent of intellectual developmental disorder, which was adopted in the first draft of ICD-11. The new terms in the DSM-V refer to a disorder with onset in developmental age that includes intellectual and adaptive deficits in the areas of conceptualization, socialization, and practical skills. Four levels of severity are distinguished (mild, moderate, severe and very severe) based both on clinical assessment and on the administration of standardized tests (Wechsler Scales) of intellectual and adaptive functions.

- Mental disability: pertains to mental and relational problems (psychosis) and psychological problems (only severe and disabling neuroses).

The subject with a psychiatric disability appears incapable, in part or totally, of fulfilling the social role required of him/her by his/her family and, in general, by the context in which he/she lives. We speak of primary disability to define the intrinsic damage induced by the psychiatric illness, which determines the problems and conflicts with the family and the social environment. Secondary disability is the adverse personal reactions. The effects of a severe mental crisis may, for example, be a total loss of self-esteem or, conversely, denial of the disorder itself. Tertiary disability is constituted by the social handicaps resulting from the disease: poverty, loneliness, lack of work and housing are factors that amplify the basic disease, leading the patient to a condition of insecurity and progressive isolation.

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In reality, disabilities often exist side by side: in this case we can speak of multiple disabilities. It is sometimes possible to specify the main disability and the associated disability. The presence of disabilities very often creates psychological and relational problems.

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1.3 European regulatory system on disability and inclusion

The European Union began to address disability from the second half of the 1970s (Priestley, 2007). At first, actions in the Community were marginal and mainly took place through non-binding instruments or through the exchange of information between member states (Waddington et al., 2002). In fact, the rights of people with disabilities were alien to the European legislative context and the treaties in force back then did not contain any mention of disability.

The approval of the European Community Disability Strategy in 1996 represents the first recognition of disability as an area of European policy and the first real affirmation of the need to protect the rights of people with disabilities through a series of integrated and coordinated actions. The Strategy in question was characterized by a change in perspective inspired by the Standard Rules for the Equalisation of Opportunities for People with Disabilities (approved by the United Nations in 1993) and by the emergence of the so-called "social model of disability" (Barnes, 2008), which conceives of disability as a consequence of social factors and not as a consequence of an individual's impairment.

With the entry into force of the Treaty of Amsterdam in 1999, the EU acquired the power to adopt measures to combat discrimination inter alia based on disability (Article 13 TEC, now Article 19 TFEU).
To date, however, the most important piece of legislation remains Council Directive 2000/78/EC which establishes a general framework for equal treatment in employment and occupation, which is the first real legislative intervention aimed at guaranteeing the right to work for people with disabilities.

In 2000, the Nice European Council approved the Charter of Fundamental Rights of the European Union, which includes two measures specifically related to disability. Article 21 affirms the principle of non-discrimination, while Article 26 states that the EU "recognizes and respects the right of persons with disabilities to benefit from measures designed to ensure their independence, social and occupational integration and participation in the life of the community" (Ferri, 2016).

In 2009, the entry into force of the Lisbon Treaty brought about a substantial change in the status of the Charter of Fundamental Rights of the EU: it was given the same (binding) legal value as the Treaties, thus making it a source of primary law.
The ONU Convention on the Rights of Persons with Disabilities (Law n. 18 of March 3, 2009) commits all signatory states to provide for forms of school integration in mainstream classes. In the introductory part of the UN Convention, the "Social Model of Disability" is affirmed, according to which disability is due to the integration between the person's functional deficit and the social context. It then goes on to examine the quality of life of the person with a disability.

Subsequently, the Commission adopted the European Disability Strategy 2010-2020. This new Strategy appears to be strongly influenced by the social model (Barnes, 2008) and the ONU Convention (2006), its conceptual and programmatic pivot is the elimination of barriers in favour of the participation of disabled people in the social, cultural and economic life. The main new element lies in the identification of eight specific areas in which the European Union proposes to act in conjunction with the Member States: accessibility, participation, equality, employment, education and training, social protection and health (Ferri, 2016).

Examples of policies are the Union's passenger rights rules ensure that people with disabilities have access to air, sea, rail and road transport, Directive 2016/2102/EU on the accessibility of public sector bodies' websites and mobile applications, Directive 2000/78/EC establishing a general framework for equal treatment in employment and occupation.

Despite all the efforts undertaken, the European Commission recognizes that people with disabilities still remain at greater risk of poverty and social exclusion than people without disabilities. Moreover, the COVID-19 pandemic has exacerbated existing inequalities. Therefore, a new strategy was proposed: the European Strategy 2021-2030. Furthermore, in 2024, the Commission itself, in cooperation with the Member States, intends to introduce a European quality framework for excellent social services for people with disabilities; to have concrete initiatives taken at the national level on access to inclusive schools, justice, and health care; and to strengthen the participation of people with disabilities in arts and culture, recreation, sports, and tourism (European Commission Communication, 2010, 2021).

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1.3.1 Regulatory system in Italy

The pedagogical model of the Italian school, judged throughout the world as the most advanced, has been characterized by a series of regulations. Starting from the concept of "school integration" of people with disabilities, Italian legislation today speaks of "inclusion". Law n. 118/71 establishes that even disabled pupils must fulfil their schooling obligation in ordinary schools, with the exception of the most serious ones (among which are considered the blind, the deaf, the intellective and the severely motorized, such as quadriplegics, i.e., those unable to move their four limbs and often unable to speak). The concept of Social Integration began to make its way and also intervened in the field of economic and health assistance (free use and adaptation of public transport) and the removal of architectural barriers (ar.27).

With Law n. 517 of 1977, an advanced pedagogical-educational model was born in our country, based on the scholastic integration of the disabled, abolishing the differential classes. This law establishes the principle of inclusion for all disabled pupils in elementary and middle school from 6 to 14 years of age who were supported by a specialized teacher for "educational support" (included in the compulsory schooling) and an administrative and financial planning agreed upon by the State, local authorities and local health units).

C.M. 262/88 promulgates the enrolment and attendance of disabled students in secondary school.

Law n. 104 of February 5, 1992, better known as Law 104/92, is the legislative reference "for assistance, social integration and the rights of handicapped persons". The main recipients of Law 104 are disabled citizens, i.e. people who have a physical, psychic or sensory impairment, stabilized or progressive, that reduces their ability to learn, relate or work integration and that determines a social disadvantage and marginalization, but there are also references to those who live with them, often caregivers of these people. The assumption is in fact that autonomy and social integration are achieved by ensuring the person with a disability and his family adequate support.
The main purposes of the law are to guarantee the human dignity, freedom and autonomy of the handicapped person, full integration in the family, in school, in the world of work and in society in general; to prevent and remove the invalidating causes that do not make possible the full realization of the person, the achievement of maximum autonomy compatible with the handicap and the full participation of the handicapped person in social life and the complete realization of civil, political and patrimonial rights; to guarantee the functional and social recovery of a person with physical, psychic and sensory impairments; to ensure care and services for prevention; to eliminate all forms of marginalization and exclusion.

These objectives are pursued through the means outlined below:

- Research in all relevant areas
- prevention, diagnosis and early treatment of disabilities
- continuous information to families
- involvement of the family in the choice of interventions

- Psychological support to the family
- guarantees the choice of the most suitable interventions
- promotion of the overcoming all forms of marginalization and social exclusion

The verification of the handicap, of the necessary interventions and of the overall residual capacity are carried out by the local health unit through medical commissions. The assessment of the handicap is an indispensable step to establish the right to access a series of tax, work, school or other benefits.
Depending on the level of severity of the disability and whether or not a joint request for a civil disability assessment is made, the person may have access to different benefits. The medical team must distinguish between two levels of severity of the handicap resulting from the disability: a permanent handicap; a permanent handicap in a situation of gravity. Based on this preliminary distinction, the person with a disability will be able to access various services. In the case of recognition of the state of handicap in a situation of gravity, the benefits are not only addressed to the person in question, but also to the parents, relatives or relatives-in-law of the person with a disability.

In 1999, Law n.68 of 22 March, Regulations for the right to work of the disabled, represents a further step of civil normalization on disability. This law, which integrates and develops Law n. 482 of April 2, 1968 that "Disciplines compulsory hiring by public administrations and private companies", introduces the concept of "targeted employment" (art.2). Articles 3 and 4 of the law clearly promote and support the individualized insertion of persons with disabilities into the world of work on the basis of an analysis of the individual's ability to work and the characteristics of the workplace. It encourages the activation of positive supportive actions and provides for the removal of environmental and relational problems that make it difficult for persons with disabilities to enter the workforce. The subsequent Presidential Decree n.333 of 2000 regulates the subject matter dealt with in Law n.68/99 and Law n.53 of 28 March 2003 defines the general norms on education and the essential levels of performance in the field of education and professional training.

1.3.2 Regulatory system in Spain

The legal landscape regarding the rights of people who live with some kind of disability, in Spain, has changed and improved continuously in recent years. The ultimate example of this legal development is the Law 8/2021, which came into effect in September of 2021, and which regulates for any person with mental and physical disabilities their full faculty of self-determination in accordance with their desires, feelings and aptitudes to the extent that they can be satisfied. In other words, people with disabilities can always take their own decisions, and are legally treated as persons and only subsequently as persons with some impairment, so that they cannot be deprived of the ability to live according to their wishes and values. This legal development follows a United Nation initiative of 2006.

But the evolution up until the Law 8/2021 starts earlier: the Spanish Constitution of 29th December 1978, reserves several articles to regulate the respective policy for people with disabilities. The current Spanish Constitution contemplates and refers to the rights of people with disabilities, approaching the matter from a double perspective, in the first place it seeks the absence of discrimination of any kind and on the other hand, it regulates the actions of the public authorities so that carry out an integration policy (Blasco Madrigal, 2021).

Almost at the same time, in 1979, the legal basis was produced for the working life of citizens with some kind of disability. Today, these labor and workplace aspects of discapacity are being regulated in the current Workers' Statute is regulated in Royal Legislative Decree 1/2015, of October 23, in order to integrate new labor laws duly regularized, clarified and harmonized. The current regulation responds to the expected development of the duty and right to have a job, protecting conditions such as fair remuneration and absence of discrimination in labor relations (Blasco, 2021).

Since 1982, the year in which the first law aimed at regulating care and support for people with disabilities and their families was passed, several regulations have been passed with the aim of improving the situation of this group. In 1982, the LISMI- Law for the Social Integration of Disabled persons- took effect. One of the most revolutionary measures introduced by LISMI was the establishment of a percentage quota of 2% of people with a degree recognized disability greater than 33% for companies with more than 50 people on staff. Finally, after more than 30 years, the

LISMI was replaced by General Law on the Rights of Persons with Disabilities and its Social Inclusion, which was approved in 2014. Some of the most important aspects of this law include new features such as the modification of the Organic Law of the General Electoral Regime to guarantee the right to vote for all persons with disabilities.

Approved in 2003, the Law of Equality, Non-Discrimination and Universal Accessibility created to unify the conditions required by the Autonomous Communities and City Councils, seeking to guarantee the right to equality of opportunities for people with disabilities. Its three main objectives are: 1)To have a legal tool with which to penalize and sanction those people or institutions that discriminate in any way against people with disabilities. 2) To guarantee and improve universal accessibility, which makes it possible for people with disabilities to lead an active and independent life. 3) Positive action, which refers to a set of policies and practices developed in order to increase the representation of the group of people with disabilities. Incorporating tools and programs for special accessibility and non-discrimination to achieve greater awareness, commitment to technological innovation and establishment of ethical norms. To guarantee the rights of people with disabilities, the LIONDAU lays the foundation for a complaints and suggestions program through which one can report any violation of the rights of people with disabilities to the Administration.

In 2021 Congress approved a law that eliminates the legal incapacity of people with disabilities. With this reform, the State eliminates the figure of legal guardian, replacing it with a support system adapted to the needs of each person.

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Royal Legislative Decree 1/2015, of October 23 https://www.boe.es/buscar/pdf/2015/BOE-A-2015-11430-consolidado.pdf

Law 8/2021, of June 2, which reforms civil and procedural legislation to support people with disabilities in the exercise of their legal capacity. https://www.boe.es/buscar/act.php?id=BOE-A-2021-9233

1.3.3 Regulatory system in Czech Repubblic

The integration of the disabled into society, their right to education, employment, and the right not to be discriminated against by anyone is established in the Czech legal system in several individual laws.

Social Services Act: Act. No. 108/2006 Coll.

The main goal of the law is to create conditions for satisfying the natural needs of people, in the form of support and assistance in managing self-care, necessary in self-sufficiency for a full life and in life situations that can exclude a person from the ordinary life of society. Social services enable a person at risk of social exclusion to participate in the daily life of society, which means access to education, employment, and cultural and social life.

Act on Preschool, Basic, Secondary, Higher Vocational and Other Education (School Act) Act. No. 561/2004 Coll.

Education of children, pupils and students with special educational needs: a child, pupil and student with special educational needs is a person with disability, handicap or social handicap.

Disability is, for the purposes of this Act, mental, physical, or visual hearing impairment, speech defects, multiple impairment, autism and developmental learning or behavioural disorders.

For the purposes of this Act, a health impairment is a long-term health impairment illness or mild medical disorders leading to learning and behavioural disorders that require consideration in education.

For the purposes of this Act, social disadvantage is:

- a family environment of low socio-cultural status, a threat to socio-pathological phenomena,
- prescribed institutional care or imposed protective education, or
- the status of an asylum seeker and a participant in the procedure for granting asylum in the territory of the Czech Republic pursuant to special legislation.

Employment law: Employment of people with disabilities Act. No. 435/2004 Coll.

Natural persons with disabilities (hereinafter referred to as "persons with disabilities") provides increased labour market protection.

People with disabilities are natural persons who are:

(a) recognized by the social security institution in third-degree disabled persons (This amendment shall enter into force on 1 January 2010.) (Hereinafter referred to as "persons with Disabilities"),

(b) recognized by the social security authority as disabled in the first or second instance (This amendment shall enter into force on 1 January 2010.)

(c) recognized by a decision of the Labour Office as handicapped (hereinafter referred to as "persons with disabilities")

For a handicapped person according to paragraph 2 letter c) is considered physical a person who retains the ability to pursue a permanent job or another gainful activity, but its ability to be or remain integrated, to pursue existing professions or to use existing qualifications or qualifications are significantly reduced due to her long-term unfavourable health condition. It is considered a long-term unfavourable health condition for the purposes of this Act an unfavourable condition which, according to medical science, is expected to last for more than one year; and significantly reduces mental, physical, or sensory abilities and thus ability employment.

2.4 Anti-discrimination law Act. No. 198/2009 Coll.

Act No. 198/2009 Coll., On equal treatment and on legal means of protection against discrimination and amending certain laws (Anti-Discrimination Act). For the purposes of this Act, the right to equal treatment means the right not to exist discriminated against on the grounds set out in this Act. Discrimination is direct, indirect harassment, sexual harassment, and harassment; for discrimination is also considered to be an instruction to discriminate and incitement to discrimination.

Disability is understood for the purposes of this Act

(a) loss or limitation of physical, sensory, or mental functions,

(b) anatomical loss, including deformity or mutilation of a body part,

(c) the presence of a micro - organism, organism, or other extraneous matter in the body which: cause or may cause chronic illness,

(d) disease or functional disorder, necessitating the application of special forms, methods, and educational progression, or mental or behavioural disorders.

1.3.4 Regulatory system in Luxembourg

In Luxembourg, the legal framework have been very much related to providing financial assistance to people with disabilities, adapting the public infrastructure and fighting discrimination in terms of employment, with school inclusion recently considered a national priority.

"A special supplementary allowance, which is set at €200 per month, is paid for a child with disability, but is dependent upon receipt of the family allowance, and the child must have one or more conditions that constitute a permanent deficiency or reduction of at least 50 per cent of his or her physical or mental capacity". The "disability pension paid out, on the basis of 40 years of work, is €1,841.51. If the insured person has not completed the 40-year qualifying period but can prove that he or she has been insured for at least 20 years, the minimum pension is reduced by one fortieth for each missing year". "Savings, subsidies and grants are available for adaptation of housing to the needs of persons with disabilities". Finally, "under the Convention on Social and Educational Support, the Ministry of Family Affairs, Integration and the Greater Region provides financial support to persons with disabilities who use residential or daytime activity services" but it is highlighted that the Ministry "cannot afford to cover the cost of those services in full" (Interministerial Human Rights Committee, 2020).

Assistive devices (e.g. walking frames, wheelchairs, special beds, adapted vehicles) and home alterations (e.g. walk-in showers, lifts, concrete ramps) have been made available to persons with disabilities with a view to maintaining or increasing their level of independence. The maximum amount that can be claimed stands at EUR 26,000 (ANED, 2019). A significant improvement should be seen in the coming years with the development of a personal assistance budget system by 2023 (Ministère de la Famille, 2019), but the modalities and amount allocated to this new measure aren't yet known.

Efforts are being made to promote access to employment through a legal quota system as well as subsidies and financial incentives for employers. However, the fact remains that "in all EU countries, persons with disabilities are more likely to be poor and unemployed than persons without disabilities. In Luxembourg, the percentage of people with disabilities in employment is 53,6% and the one of the people with disabilities at risk of poverty and social exclusion 28,8%. The situation has worsened by 9% since 2010 as far as the latter figure is concerned" (EDF, European Human Rights Report 2020: Poverty and Social Exclusion, 2021). Though Luxembourg provides assistance in training for people with disabilities ((EDF, European Human Rights Report 2020: Poverty and Social Exclusion, 2021), gaps remain in this field as well as in terms of access to education: "only one in eight women with disabilities has a tertiary degree in Luxembourg, compared to one in six men with disabilities" (EIGE, 2017).

Following recommendations from the UN Committee on the Rights of Persons with Disabilities, recent laws have introduced a number of new measures at national level:

- the establishment of a mediation service for school inclusion and integration (Law of 18 June 2018)
- the creation of specialised psycho-pedagogical competence centres for school inclusion (Law of 20 July 2018)
- the recognition of the German sign language as a language in its own right (Law of 23 September 2018)
- the creation of specific employment inclusion assistance activities for disabled employees (Law of 1 August 2019)
- measures ensuring the accessibility to all places open to the public, public roads and collective housing buildings (national bill N°7346)
- the creation and use of a parking card for disabled persons (bill approved by the Government Council in its meeting of 11 July 2019).

In spite of those laws, problems are still reported in the accessibility of buildings and infrastructure for public use (Arthur Limbach-Reich, 2021). The situation is especially challenging for private buildings (and housing since the offer in Luxembourg is very much focused on individual houses) and for some specific categories of disabled people, such as the blind. "Disability is often seen as a person sitting in a wheelchair and measures are based on this paradigmatic model, so that especially for people with cognitive impairments and psychological problems no adequate support measures result" (ANED, 2019).

Some public inclusion schemes are considered too restrictive and are available to a limited number of people due to the classification system. The accessibility coordinator at Info-Handicap cites the example of the On-Demand Transport for Persons with Reduced Mobility service in Luxembourg (Adapto)," which isn't available to people who have a driving licence, but experience days when they are unable to drive. This is for instance the case of people suffering from multiple sclerosis, whose physical condition can vary from day to day" (New mobile app for Adapto service launched , 2021). Individuals with disabilities criticised that people whose mobility is only temporarily restricted cannot use the services of Adapto. It is also problematic that the accompanying of caregivers is restricted (Arthur Limbach-Reich, 2021).

Luxembourg legislation does not provide for a definition of the terms "handicap" or "disabled or 'disabled person' and benefits vary according to different types of impairments or disabilities. It is moreover to be noticed that disability is still being assessed in Luxembourg according to an official barema based on medical considerations, while a functional or ideally thoroughly holistic approach would be recommended (EDF, European Human Rights Report 2020: Poverty and Social Exclusion, 2021).

In 2017, United Nations Committee Experts noted with concern that the medical approach to disability continued to be deeply rooted in the legal system and practices, and that the focus remained on the lack of capacities rather than on social barriers. There was no unified definition of disability which allowed for differences in the treatment of persons with disabilities from one institution to another (OHCHR, 2017).

In the last five years, things haven't much evolved from that point of view. European Disability Expertise, an independent organisation who provides scientific support to the Commission's policy Unit responsible for disability issues, thus recently highlighted the need for Luxembourg to adopt laws and policies "based on a global/holistic understanding of disability (which is not a form of illness) and the needs of people with disabilities for health services, in one hand, and a sound understanding of the specific types of disability and their implications on the design of medical services in terms of usability, effectiveness and efficiency, on the other hand" (Arthur Limbach-Reich, 2021). The new approach to be implemented in the DEEP project is therefore especially relevant in the national context.

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2. The role of technology in the world of disability

We live in an era in which we have witnessed and continue to witness the birth and spread of digital infrastructures and tools, mobile devices, broadband Internet connections and digital aggregation and recomposition platforms, smartphones, tablets and other tools such as wearables, that allow you to be connected 24 hours a day in any place reached by a connection. This is the infrastructural skeleton that has allowed the development of "digital" technological innovations over the last few decades, characterized by the transition from mechanical and analogue technology to digital electronic technology. We are therefore talking about social media, cloud computing, big data, wearable devices, 3D printing, artificial intelligence systems and machine learning. The extent of this incredible series of changes cannot be reduced to a simple succession of technological innovations: there is much more. What we are facing today is a real (digital) revolution that changes the paradigms in which we live and operate. Digital innovation can be defined as the set of "products, processes or business models that are perceived as innovative, require a significant change on the part of those who adopt them and are enabled or incorporated in the use of digital technologies". More generally, we talk about the "digital revolution" because the extent of these changes has profoundly affected the way companies live, work, manage and, in many cases, have led to a change in the structure and characteristics of entire sectors. Digital innovation arises in part from a new way of thinking and reasoning, while on the other hand it introduces completely different approaches from those we were used to; for this reason it would not be correct to talk about a simple sum of new tools available to human beings.

In the current panorama, as well as the type of innovations, the following main categories of digital and technological innovation capability can be mapped:

Apps and mobile devices

Internet of Things

Robotics:

3D printing

Artificial intelligence (AI):

Machine Learning (ML)

• Virtual Reality (VR):

• Augmented reality (AR)

• Wearable devices or "wearables"

The use of the same categories of digital technological innovations may vary based on the type of user and the context in which they are applied. Technology can establish or facilitate:

• The direct relationship between two users, considered equal to each other;

• The relationship between an organization or institution and the reference user;

• The relationship between two users or between organizations and users, but through the active role of an intermediary

• The relationship between workers of an organization or institution;

• The relationship between the organization and its workers.

The digital revolution has introduced a profound paradigm shift, presenting opportunities to give new or better answers to the needs of citizens, but at the same time bringing with it some elements of uncertainty. Digital innovation can be inclusive, but it can also exclude those who do not have the means to govern it; it can generate negative organizational impacts, but also facilitate the processes of providing services and using resources; can improve the ways of interacting with the final users of the services, but also overshadowing the value of the direct relationship with the professionals who offer these services.

A new way of responding to increasingly complex needs and challenges can be identified in the concept of Social innovation used to indicate: new solutions (products, services, models, markets, processes, etc.) that simultaneously satisfy a social need (in a way more effective than existing solutions) and lead to new or improved skills and relationships and better use of assets and resources (Caulier-Grice et al., 2012: 18).

From the Technical report Vision and trend of social innovation, by Addarii, F., & Lipparini, F. presented to the European Commission in Brussels in 2017, among the trends that characterize social innovation identified in the literature technology stands out, due to its capacity to determine new ways of interacting, socializing, communicating, consuming, sharing content.

In a recent KPMG publication, sixteen experiences of social innovation at local level born in the welfare sector were traced and analyzed: among these, seven included technological innovations or elements aimed at reducing the digital divide in their service / intervention model. it seems that from the union of technological innovation and social innovation, experiences capable of expanding the perimeter of intervention and traditional users of services can flourish: the change is also taking place in the way of thinking and in the expectations that each one cultivates towards the use of goods and services.

Thinking that welfare services are immune to this paradigm shift would be shortsighted and reductive, just as it would be completely incorrect not to take into consideration that the impacts of the digital revolution should be contextualized with respect to the peculiarities of the sector.

The process of introducing innovations in services should therefore take into consideration some "crucial" steps

• First, to encourage the circulation of knowledge to define as fully as possible the functioning of the digital innovation introduced;

• The second step should involve an effort of persuasion to generate or increase the favorable attitude towards technological innovation;

• The third phase is the one that provides for the definitive acceptance of the introduction of digital innovation within the services;

• The fourth step consists in the assessment by the actors of the actual positive contribution of digital innovation in the context of the activities and daily routines related to the services provided;

• The last phase is the definitive adoption and belief in the centrality of the digital innovation introduced, which thus becomes an element accepted and evaluated as compatible with the internal and external reference context.

Concerning the specific role of technology in the world of disability, innovation is mainly applied in rehabilitation contexts, where artificial intelligence and robotics have been introduced for years, see for example the case of the exoskeleton, a robotic structure equipped with electric motors and circuits that allows the path to para and quadriplegics, or people who have injured the spine due to a trauma or disease and are no longer able to move limbs. In the world of more traditional services for people with disabilities (residential / semi-residential structures), the technologies introduced include innovative elements to increase the degree of personalization of the service and, where possible, facilitate the self-management of people, with the aim of making independent living possible (e.g. Open Hospital, software for the management of rural hospitals)

For people with disabilities, computers, smartphones, Internet and the multimedia world have the potential to free creativity, increase personal autonomy, make leisure activities possible, allow work and social participation. But this is possible only if the peripherals and services are designed to be accessible. Assistive technology is defined as: "... any article, part of equipment or product, whether commercially acquired, modified or customized, which is used to increase, maintain or improve the functional capacities of persons with disabilities". Assistive technologies have as their purpose the elimination of differences in performance between two individuals, through a series of solutions that can be summarized as follows:

• restore a function

• overcome a barrier

• remove a barrier

• amplify a stimulus

• overcome an interrupted function

• convert and re-direct a stimulus

Basically, there are two ways to reduce the gap, namely:

- increase personal skills with the use of assistive technologies, or

- lower the minimum requirements of a product through a design ... universal. Examples of assistive technologies are: - mechanical aids for walking, eating, dressing, using the toilet, etc. - easy reading glasses - modified vehicles - handles, ergonomic switches - emergency alarms and sensors

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Assistive technologies for movement disabilities: - changes to the accessibility of the home - prosthetic limbs - sitting aids - electric or manual wheelchairs - accessible design of a living space

Assistive technologies for visual impairments: - Augmented and Alternative Communication AAC devices - symbolic communicators for dyslexia - TTS speech synthesizers - Braille devices

Assistive technologies for hearing impairments: - ASR speech recognizers - hearing aids, cochlear implants - manual or automatic captioning - automatic sign language converters

Assistive technologies for computer access: - facial (face tracker) or pupil (eye tracker) pointers - special mice and trackballs - joysticks and mice controlled with lips - special keyboards - virtual on-screen keyboards - face scanning methods - Brain Interface Systems (BCI).

The scenario of opportunities that, for example, mobile devices can offer to a disabled user is rich and varied. The mobile paradigm can allow a sighted person or a partially sighted person, for example, to access information, in audio format, through the Text To Speech, in all those contexts in which there is an exclusively visual communication, such as information on the starting track of station trains, timetables and directions on bus routes and delays at stops, service information in a hotel, etc.

The smartphone can also replace a PC: the greatest opportunities have been found in the case of blind people. It has, in fact, usability characteristics preferable to a computer, thanks to its small size and to the guarantee of greater ease of use (the mobile phone is wireless, does not present network connection problems and, in most cases, is already on at the time of use).

2.1 The use of technological devices in disability

Technical compensations have made enormous progress without eliminating the impairment, but by "erasing" the situation of disability. There is hope for substantial progress in the years to come with the progression of key areas of technology (biomaterials, electronics and microelectronics, sensors, computer and communication software, nanotechnologies, robotics and home automation, implants, body imaging) (Rabischong, 2018).

While yesterday's bionic technology was bulky and expensive, 3D printing and body-machine interfaces (BMIs) are making it easier and cheaper to make prostheses (PWC, 2019).

Additive manufacturing is increasingly taking innovative approaches to create new assistive devices with new design like wheelchairs (Jamaa, 2021).

Innovations in the field of wheelchairs include alternative power sources, new assistive robotics and intelligent systems to help wheelchairs overcome obstacles or self-adjust, human machine interfaces the may help the control of mobility devices and robots with the brain, eye movements, facial gesture recognition or other systems (Dicianno, 2018)

Maturolife is an H2020 European project that used creative and artistic design and advanced materials innovations to produce assistive technology prototypes. It demonstrated the potential of smart materials for such purposes as well as the interests and needs of the end users for materials allowing control of the skin temperature, cooling and heating solutions, footwear that improves balance, sensors to detect ground or floor surface texture, as well as smart furniture, supporting safety and independence at home but also enabling improved sleep and mobility (through e.g. ergonomic functions to support the sit/stand movement).

In the field of rehabilitation, gamification is a key methodology and support tool which can be further supported by technologies. "A customizable game personalized to the individual condition is one of the innovative ways of retaining or enhancing individuals' motivation in going through rehabilitation training, as the road to recovery can be a long process". "It can be concluded that this area of research has a lot to offer, especially in the health domain. Thus, as technology continues to develop and integrate into healthcare, further exploration has to be conducted for better rehabilitation outcomes" (Nooralisa, 2021).

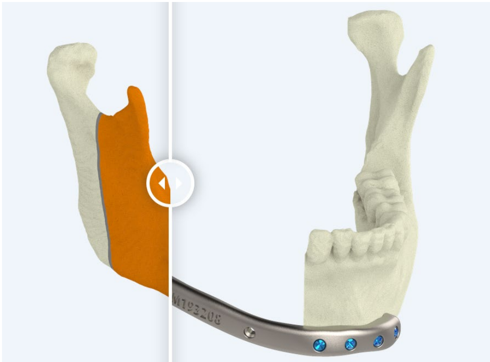
The question of the development of mainstream technologies that would be able to replace traditional assistive tools has been studied in the recent literature. It seems that this evolution mostly applies to blind and low vision impaired people. "This is especially true for object identification, navigation, requesting sighted help, listening to audiobooks, reading eBooks and optical character recognition"; however, smartphones and tablets "cannot replace the use of traditional tools for the completion of certain tasks, particularly as these pertain to extensive typing and editing needs" (Natalina Martiniello, 2022).

In the emerging assistive technology space, the most active domain over the recent period is hearing, followed by mobility, vision and communication. Emerging products and devices introduce advanced versions of conventional assistive products, namely advanced walking aids
(balancing aids and smart canes), advanced prosthetics (neuroprosthetics, smart and 3D printed prosthetics), advanced wheelchairs (including self-driving wheelchairs and wheelchair control) and exoskeletons (full-body exosuits, lower and upper body exoskeletons and control thereof) (WIPO, 2021).

The report states that the major developers of assistive technologies are big specialised corporates, which is a bit influenced by the fact that the report includes patented assistive technologies only. Here are some examples of innovations developed by young entrepreneurs and start-up companies which are improving the life of people with disabilities:

Wandercraft, Marsi Bionics and Exoatlet offer exoskeletons for the rehabilitation of paraplegics or hemiplegics, while Xilloc Medical aims to provide patient specific implants to reconstruct parts of the human's skeleton.

Exoskeletons



3D reconstruction

ReFlex uses motion tracking sensors for improving knee and back rehabilitation programmes.

Sensors

Cynteract is an intelligent glove with sensors that patients can use as a game controller in rehabilitation.

BionIT Labs has developed the world's first fully-adaptive bionic hand and Emovo a portable and lightweight hand orthosis that allows you to grasp and release simple objects at home.

Open Bionics, a UK-based startup has developed a 3D printed prosthetic hand that costs a fraction of what is currently available in the market while Reboocon offers prosthetic knees and ankles.

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Scewo is a compact, self-balancing wheelchair that allows people to climb obstacles like stairs.

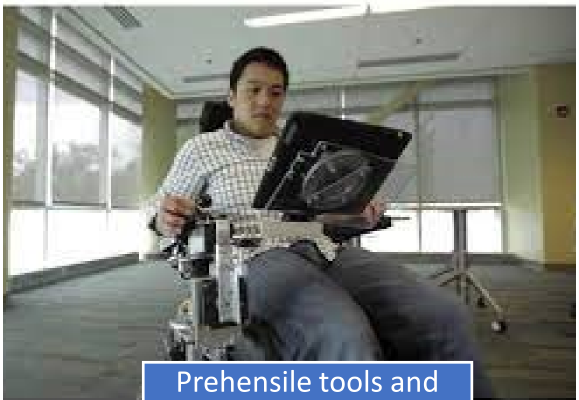
Wheelchairs

Gyrolift is an inclusive mobility solution based on the combination of a gyropod and a robotic system of stabilised modular seating that allows people to move around both sitting and standing. It offers automatic stabilisation, a safety system and intuitive control, enhancing comfort when moving.

Other mobility solutions

WheelAir has developed a temperature control system designed to fit all wheelchairs, improving the skin microclimate of the end users.

Prehensile Technologies, a spin-off from Purdue University, commercialises a robotic wheelchair mount for mobile devices. It allows a user to independently deploy, position, and store mobile devices using accessible switches from a power wheelchair. The product uses a motorized mount on a wheelchair that utilizes an arm to deploy or retract a mobile electronic device such as a tablet or lightweight notebook. The assistive tray's multifunctional design enables it to be used for other purposes, such as a writing surface or meal tray.



Prehensile tools and accessories

Streetco is the first collaborative pedestrian GPS adapted to people with reduced mobility that alerts to obstacles on the path and finds accessible places around the user.

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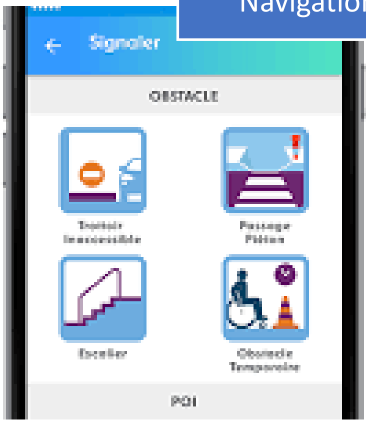
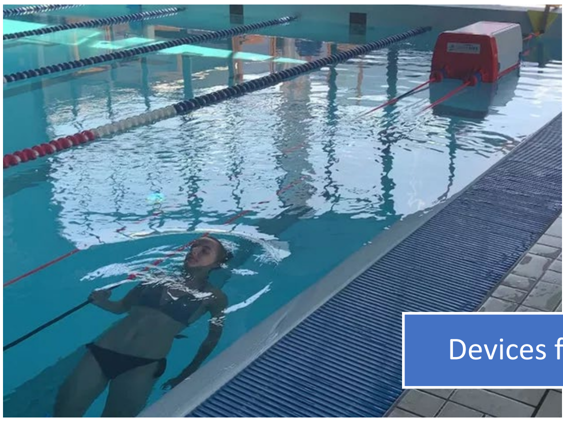
Navigation aids



Swimlift is an innovative support for movement in the water for people with reduced mobility through the use of a conveyor, moved by an electric battery-powered motor, which operates on the surface of the water at low speed between two pulleys suitably mounted on small stations to ensure safety.



Devices for sports

Munevo Drive is a proportional head control for electric wheelchairs and many other devices. It is based on Smartglasses and helps people with disabilities to achieve independent mobility and more self-determination.

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Robotic controls

Leka has developed a small robot dedicated to exceptional children (autistic, Down's syndrome or multi-handicapped). The sensory stimuli (colours, sounds, vibrations, emotions, movement) aim to arouse the child's interest and help him/her to interact with his/her environment. The educational applications are designed to help the child progress while having fun.

Assistive Robots

Sovi has developed Talkii, a digital companion for people with communication disorders. Talkii is an Augmentive and Alternative Communication (AAC) software which enables language development, growth of communication skills and helps the users to get self-dependent through the daily activity functions. Talkii reduces frustration and difficult situations in families. Talkii is used in hospitals, rehabilitation centers, special education centers and suits for Autism, Aphasia, Verbal apraxia, phonological disorders, lateral sclerosis, down syndrome,…

LuxAI offers an expressive social robot designed to support a variety of use-cases including education of children with autism and other special needs. The robot is an easy-to-use assistive tool for increasing children's engagement at school or at home.

BJ Live makes adapted toys for children with spinal cord injuries, multiple sclerosis, neuromuscular disorders, cerebral palsy, autism spectrum disorder or learning disabilities.

Adapted toys

Braibook is the first braille E-reader, developed with the collaboration of braille users and for the community of people who are blind or have low vision.

FeelObject offers Virtuoz, the first tactile and interactive 3D plan that allows visually impaired or blind people to move independently in and around buildings

Vision aids

Tactile aids

Give Vision has created a wearable device that uses AR and VR to enhance vision. The device, called SightPlus, enables wearers to go about their daily activities with greater independence.
Vibrosonic offer an innovative hearing aid that sits directly on the eardrum and transmits sound through direct stimulation, exactly like the natural hearing process.

Aside hearing aids, assistive technologies for hearing impaired people include devices such as Smarthear, a fixed box that captures sounds in real time and transmits them as light signals to a portable box. Smarthear can record and identify up to 28 different sounds.

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qaqAssistive technologies can be classified from low-tech to hich-tech. This state of the art focuses on the ones which are market-ready and not utterly out of the reach of the stakeholders in DEEP because of their cost or complexity to implement (e.g. implants, bone substitutes or brain–computer interfaces which could enable new ways to control assistive devices but are still in development). For some high-tech products, inspiration can be found from products especially designed for low-income settings or developed in the context of open innovation schemes.

3D Sierra Leone is a Dutch project established in 2018 to improve prosthetic facilities in low- and middle-income countries. In collaboration with the 3D-Lab at the Radboud University Medical Centre in Nijmegen, they set up a pilot 3D laboratory in Masanga Hospital in rural Sierra Leone, exploring 3D-scanning and 3D-printing techniques to locally manufacture affordable prosthetic aids that meet the necessary standard.

Non profit organisations are contributing to the development of assistive technologies in Europe with a number of affordable and inspiring solutions. Lichtwerk thus developed an augmented reality (AR) solution combining AR software, projection technology, 3D cameras and sensors, that provides workers with digital work instructions in an interactive way, in order to adapt the workplace to the needs of people who cannot easily handle text-based or oral instructions.

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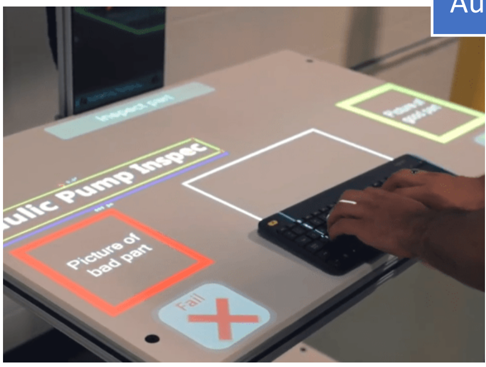
Augmented reality



The UK Charity Motivation illustrates how technologies can support a very important aspect of assistive tools, which is the ability to fully customize them to the needs, tastes and resources of the end users. They are using computer-aided design and additive manufacturing to better inform their design and manufacturing processes, and apply it to wheelchair provision. Digital measurements of patients and high quality personalised 3D printed postural support devices allow them to offer fully tailored seating solutions for disabled people.

It is to be noted that the design of assistive technologies (AT) and their aesthetics play an important role in the usability of the tools. "In addition to the functionality of assistive devices, their aesthetics can also influence the relationship between product and user". "The aesthetics of assistive devices was observed as an important factor that influences the adoption or abandonment of the device" (Aline Darc Piculo dos Santos, 2022). There is "no resistance to the adoption of smart materials and technologies if they are integrated into AT products that are easy to use, comfortable and aesthetically pleasing, irrespective of the complexity and novelty of the technology involved (Moody, 2021).

Further examples of emerging tools include some assistive technologies that were developed by students in the framework of start-up competititons or ideation programmes.

In 2017, students from the engineering school Polytech in Nancy (France) thus decided to make life easier for visually impaired or blind people by proposing to use a connected cane to guide them by obtaining their location. The technology no longer uses guidance strips but a connected box installed on the cane that transmitted information in the same way via headphones. The digital box, Sherpa by HANDISCO, consisted of a keyboard in Braille and an audible indication for switching on the device. The keyboard had only five buttons, making it easy to use. A geolocation function allowed the user to know his or her position with three markers. The headset allowed the position to be stated and thus gives directions on the button scheme. This intelligent assistant has been developed to meet the needs of visually impaired people but also of disability professionals to better understand the demand. It is a solution that complements the existing offer such as audio beacons. The idea is to collect all the

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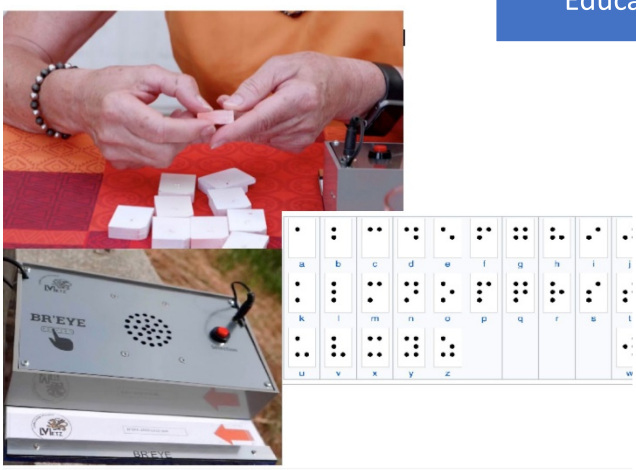
data in the space and make it available to visually impaired or blind people to give them a degree of autonomy. Public transport timetables can thus be given to users in real time.

Connected devices and

Br'Eye is another idea brought to life by an university student. This interactive device allows visually impaired and blind people to learn Braille and play board games together.

Educational tools



In North Macedonia, 17-year-old students are using 3D printing technology to create a user-friendly bionic arm that is 1/30th of the price of existing prosthetics. The students have created their own start-up: eBionics.

Projects at creative labs and universities, as well as Hackhathons are a source of open innovations which are often shared with communities of engineers, doctors and designers, and can inspire the design of assistive aids with a strong involvement of the end users.

The Assistive Technologies Innovation Centre at the University of Wales has developed a bespoke riding helmet for a child with cerebral palsy, using 3D scanning technology.

Typecase is a chorded keyboard that brings back tactility to smartphones and was developed by a mechanical design engineer at Imperial Colledge London.

Industrial designers from the Brunel University London have developed an evolvable walking aid made of a modular range of parts which can be assembled to form a walking stick, crutches, a walking frame, or variations of these aids. It saves user from having to buy a whole new walking aid when their mobility condition changes.

During the Funka-Facebook Accessibility Hackhathon 2020, one participant submitted Follow Me, a digital assistant app and device to help guide people with low vision or people with cognitive disabilities through a supermarket and find their items.

Tactile Eyesight is a community that formed during a Startup Weekend event in Latvia and is thriving to provide easy & affordable way to support blind communities by giving them easy access to 3D digital tactile layouts, building on opportunities in applying rising 3D printing technology to mass-production of tactile books, thus making them more available.

A number of innovations are developed by communities of healthcare workers with the support of 3D. That allows to make assistive technologies adapted to the needs of the end users and more affordable. The French ONG Handicap International launched a project called Impacte 3D for the benefit of disabled communities in African countries. "After eighteen (18) months of implementation, 96 people with disabilities have benefited from this new technology on 3D printing of orthotics in Bamako, Niamey, Lomé and Dapaong despite the technological difficulties encountered" (Ministère de la Santé, 2019).

Some social businesses are being created with the mission of promoting the co-design, manufacture and marketability of assistive products, making use of crowdsourcing. The founders of Participant Life in the United States seek to design a suite of products which are locally manufacturable using 3D printing and other technologies which allow high quality products to be made in small facilities. For their first product to be developed under this new participative model, they have opted for a wheelchair for kids.

Some reports state that what is actually missing in terms of tools and which is typically related to the generic ones that all citizens in a given country should be able to use. The gap is not only perceived as far as some specific assistive devices are concerned but also and possibly even more in terms of having access to ICT like everybody else. From that point if view, an experienced gap is that "the usual authentication protocols involving for example a security token are not effective in many types of disability, and more generally the human-computer interaction interface" (ANED, 2019). That prevents access to a number of online services for e.g. visually impaired. Some technologies are however already available in this field, such as Facil-ity, which adapts websites to the needs of people with e.g. low vision, Parkinson's or dyslexia. However, a token suitable for people with disabilities couldn't actually be found.

Some basic aids and accessories for improving daily life still seem not to be that easy to find on the market. "The tasks of opening and navigating through a door are trivial for healthy people, while the same tasks could be difficult for some wheelchair users. A wide range of intelligent wheelchair controllers and systems, robotic arms, or manipulator attachments integrated with wheelchairs have been developed for various applications, including manipulating door knobs. Unfortunately, the intelligent wheelchairs and robotic attachments are not widely available as commercial products" (Soran Jalal, 2018).

As far as disabled children are concerned, "the enormous value of play is still too often unrecognized. Finding and acquiring toys, which are adapted to the abilities of children with disabilities (Jansens & Bonarini, 2020) can be difficult" (Botelho, 2021).

Yet, "by means of embedded controllers and rapid prototyping techniques, it became possible for even small teams of researchers and designers to create interactive, often toylike artifacts, suitable for use by children and addressing their particular needs" (McDaniel, 2019). One example is Phonoblocks, a tangible reading (and spelling) system created at Simon Fraser University, which utilizes the some of unique opportunities of tangible user interfaces to help kids with dyslexia learn to read and write. First, the system uses embedded dynamic colour in 3D letters – the colours change to draw attention to the moment when a letter's sound changes based on the addition of another letter in a word. The 3D letters also help with letter reversals, and kids organized them spatially using epistemic strategies to simplify task and eliminate the need for fine motor control in learning to read.

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The assistive technologies available can be roughly divided into hardware and software. It is to be noticed that the software companies are typically more sustainable than the hardware ones and their solutions more affordable in terms of pricing (which in return contributes to the sustainability of the offer). "Scalability is hard, hardware is expensive. For this reasons, the market tends to go toward service rather than product" (Xange, 2020).

Barriers to the use of new assistive technologies (AT) include cost and user-friendliness. "Cochlear implants may cost up to 30,000 euros + 8,000 euros on average per update of the technology" and "barriers also remain due to lack of involvement of persons with disabilities in the designing of certain AT" (EDF, A disability perspective into our closest technologies, 2021). "Assistive technologies developed without the necessary clinical expertise may not consider, among others, the range of complexities that someone with a disability may present with, how they will access the technology, or potential secondary complications of use" (Boger, 2022).

Moreover, there is a "lack of independent information to choose the best suited technology, as well as lack of support once the AT is delivered" ((EDF, A disability perspective into our closest technologies, 2021).

By supporting the co-design and 3D printing of new customised hardware tools through adequate training of relevant stakeholders, DEEP is therefore likely to fill in an actual need on the market. There is a gap perceived in terms of usability and adaptability of the current assistive technologies (AT) available in Europe. "the different AT provision systems are not sufficiently flexible, and person-centred, and in some cases these models even discriminate against certain persons with disabilities, based on their age or work status" (EDF, A disability perspective into our closest technologies, 2021).

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3. Good practices and intervention programs on the use of 3d printing in disability

People with disabilities often need customized equipment to help them with their individual needs - could 3D printing provide a cost-effective and efficient solution? Raul Krauthausen a disabled person from Berlin bought a 3D printer a year ago, thinking it might be fun to make new iPhone covers or small key rings. After a while he wondered if he could create something more useful for himself.
"I decided to print a small ramp because I am a wheelchair user. I often have problems entering places with only one step at the entrance. I thought it would be nice if I could take one with me on the back of my wheelchair, not too big and not too heavy. I then created a couple of portable plastic wedges that act as a ramp for me. "

It is not yet a complete solution to be useful: "I have to ask someone on the street to lay the blocks on the ground for me, but this is not a problem: sitting in an electric wheelchair I am used to asking people for help".
Plastic printing materials cost 50 euros in Krauthausen and it took 26 hours to print the ramp.

3.1 Comparative analysis of good practices: disability and 3D printing

In order to compare intervention programs that are more effective in relation to the topic dealt with (disability and 3d printing) the following two searches ("comparisons") where carried out:

COMPARISON 1

Data base used:

https://cordis.europa.eu/projects/en, in: (https://ec.europa.eu/info/research-and-innovation/projects/project-databases_en)

Scope of the comparison:

Using the search engine "Cordis" of the European Union, several search terms were inserted: "prosthesis", "3d printing prosthesis", "prosthesis patient communication". In total, the research produced 23 results, of which approximately 10 dealt with prosthesis making or prosthesis related technological solutions. The selected 10 results in the list below are the ones which mentioned socio-psychological challenges for the patients related to the loss of limbs and the use of the prosthesis. This is a shared feature with DEEP.

Results of the comparison:

Examples taken from the database "Cordis" of the European Union show that, at least in a sample of 10 randomly chosen projects, there is no implicit active participation of the users of prothesis. However it is noticeable that several projects mention the social and psychological impacts of prosthesis, and envisage improvements of quality of life in the patients. It could be argued that these social and psychological aspects could be taken into account in a more interdisciplinary way by opening spaces of participation, feedback and direct contact between makers, health personnel and the users and patients.

For example, in the case of the Project "RESHAPE" it is stated, that: "It (amputation) does not only dramatically affect the sensorimotor functional ability of the subject, but also the healthiness of the representation they have of their body that is a fundamental aspect of self-consciousness." The knowledge of the psychological impact could justify a measurement of the psychological improvement of the patients as a result. So far, the Project description does not outline such results.

Conclusion of the search:

Therefore it can be stated that the Project DEEP has chosen an comparatively more holistic approach in that it has an implicit participation of patients and takes into account that the process of interpersonal communication and relation building is to be an integral part of the production of prosthesis. Thus, the psychosocial impact is built in component of DEEP and makes it more interdisciplinary in what concerns the socio-psycho-technological approach.

Search results:

Titel description	Goal / results	Leve lof comparison with DEEP
RESHAPE (REstoring the Self with embodiable HAnd ProsthesEs) https://cordis.europa.eu/project/id/678908/reporting	Amputation of the upper limb would represent a devastating event in the life of any human being, resulting in a severe disability. It does not only dramatically affect the sensorimotor functional ability of the subject, but also the healthiness of the representation they have of their body that is a fundamental aspect of self-consciousness. Amputation damages go beyond the produced functional disability, especially for unilateral amputees that partially compensate lost functions with the healthy hand. Hand prostheses are specifically designed to counteract sensorimotor impairments, but less attention has been posed so far to deal with the alteration of the image of the body that accompanies the amputation. Indeed, despite the recent technological advances in Prosthetics, too many amputees only use cosmetic prostheses or do not use them at all; an enhanced	The reasoning of the Project explanation is highly empathic with regard to the psychological situation of the patient. The Project itself does not include an interdisciplinary approach to cover these needs of the patients in combination with the development and adaption of the technological solution. Patient participation is not mentioned.

	sense of ownership of the prosthesis may likely be the key for increasing user acceptability	
Natural sensory feedback for phantom limb pain modulation and therapy https://cordis.europa.eu/project/id/602547/reporting	Amputation of a limb may result from trauma or surgical intervention. The amputation traumatically alters the body image, but often leaves sensations that refer to the missing body part. In 50-80% amputees, neuropathic pain develops, also called phantom limb pain (PLP). Both peripheral and central nervous system factors have been implicated as determinants of PLP. Also, PLP may be triggered by physical (changes in the weather) and psychological factors (emotional stress).	The Project description makes reference of emotional stress as one trigger of PLP. However, the project does not include the dimension of emotions, and does not extend the score to a more interdisciplinary psychological, interpersonal communication and relation orientation. Patient participation is not mentioned.
Titel, description **HELPING HAND: A 3D printed, affordable myoelectrical prosthetic hand of personalizeable size for optimal comfort and functionality** https://cordis.europa.eu/project/id/805900	Goals/Results The needs of prosthetic hand users are still widely unaddressed, with 1/5 of end-users giving up on prosthesis use altogether. Discomfort and poor functionality are key complaints of prosthesis end-users, with >75% considering their current prosthesis too heavy and too slow for daily use. Indeed, existing commercial alternatives fail to provide simultaneously: 1) control of prosthesis through myoelectrical sensing (i.e. sensing the remining muscles contraction to open/close the prosthesis grip and change its gesture), 2)	Although, 3D Printing is a common denomitator in comparison with DEEP, and the focus on lack of acceptance of protehsis by patients is also comparable, the Project Helping Hand does not provide an active role of

Grant agreement ID: 805900	advanced/precision gripping patterns and 3) competitive costs within reimbursable limits of several countries. In addition, competing myoelectric prosthetic hands are typically 20-75% heavier than the human hand, resulting in significant pain and discomfort from continuous daily use. (…) highly optimized use of advanced materials and 3D printing allow to bring the prosthesis weight on pair with the human hand – addressing a key end-user priority for comfort.	participation and exchange with the technological experts.
SocketSense Grant agreement ID: 825429 https://cordis.europa.eu/project/id/825429/reporting	Technical innovation to adapt prothesis to user needs: The H2020 project SocketSense aims at developing an innovative prosthetic socket system with integration of advanced sensing, data analysis, AI methods, embedded edge and cloud computing. It is motivated by the fact that limb amputations often cause serious physical disabilities and thereby compromise the quality of life of many people around the globe.	• No direct participation of patients/users • No participation of health and therapeutic personnel • Topic of Interpersonsal relations and motivation to change not covered
Socketmaster: 2015-2018 Grant Agreement	The function of a lower limb prosthetic is highly dependent upon the characteristics and anatomical profile of the residual	Although the individual adaption of the prosthesis is

Number: 645239 Project Acronym: SocketMaster Project Title: Development of a Master Socket for optimised design of prosthetic socket for lower limb amputees http://www.socketmaster.eu/	limb. This is unique to each individual and changes depending on the activities being engaged in by the amputee. A poorly fitting prosthetic socket can cause significant trauma so it is important to consider how to optimise the fit to maximise the amputee's comfort whilst wearing the limb prosthesis. Current practice in designing a prosthetic socket is time-consuming, and is highly dependent on the experience of the prosthetist.	ackmnolwledged in the description of the Project, there is no active participation on behalf of the patients.
DeTOP (Dexterous Transradial Osseointegrated Prosthesis with neural control and sensory feedback) https://cordis.europa.eu/project/id/687905/reporting	The DeTOP project targets people with reduced or absent hand sensorimotor capabilities, due to an amputation. The latter is known to cause severe physical and psychosocial dysfunction. Besides the obvious inability to grasp and manipulate objects, as well as to sense the environment through the sense of touch and proprioception, the hand may no longer be used for gestures that normally support speech and emotional expressions. Additionally, the physical differences compared to other people can result in severe psychological problems. DeTOP aims to develop the next-generation transradial prosthesis by clinically implementing robotic, sensing and long-term interfacing technologies.	Although the Project description makes reference to psychological and social impacts due to the loss of limbs, the Project focuses exclusively on technical aspects of the problem solving. Patient participation is not mentioned.
The CYBERnetic LowEr-Limb CoGnitive Ortho-prosthesis Plus Plus https://cordis.europa.eu/project/id/731931	The global goal of the CYBERLEGs Plus Plus project is to validate the technical and economic viability of the powered robotic ortho-prosthesis developed within the framework of the FP7-ICT-CYBERLEGs project as a means to enhance/restore the mobility of	Although the Project description makes reference to overall positive quality of lives effects in the

	transfemoral amputees and to enable them to perform locomotion tasks (…)Restored mobility will allow amputees to perform physical activity thus counteracting physical decline and improving the overall health status and quality of life.	patient, these effects are seen exclusively in the applicationof the technological intervention. Patient participation is not mentioned
Restoring of SENSAtions from Lost LeGs for health And quallty of life augmeNtation in amputees **Bionic legs – direct nerve stimulation restores natural limb touch and motion sensations** https://cordis.europa.eu/article/id/411589-bionic-legs-direct-nerve-stimulation-restores-natural-limb-touch-and-motion-sensations	Commercially available prostheses do not elicit any sensory feedback, risking falls and loss of confidence in the prosthesis. Amputees rely mostly on the intact limb, producing asymmetrical walking which causes long-term arthritis, osteoporosis and back pain alongside reduced mobility and increased fatigue. Moreover, the lack of any physiological connection between the prosthesis and the nervous system of the patient causes phantom limb pain. **A prosthesis that restores the feeling of touch and motion** To address this issue, the EU-funded SensAgain project designed an innovative neuroprosthesis that brings back the feeling of the lost limb.	Although the description mentions new ways of connecting the linmb to the prosthesis, no mention is being done with regard to the communication during the learning process and the relation between patient and the health and maker staff. Patient participation is not mentioned.
INTELLIGENT PROSTHESIS SYSTEM Breakthrough nerve-attached bionic leg	The proprietary prosthesis – commercialised under the trademark name Suralis – consists of a sensor sock, which detects rolling movement through a set of vibrotactile actuators. The information from the ground is then	The Project does not mention the dimension of interpersonal communication between

tackles pain for amputees https://cordis.europa.eu/article/id/358585-breakthrough-nerveattached-bionic-leg-tackles-pain-for-amputees	transmitted to the nerves of the leg and finally to the brain. As a result, the brain doesn't have to search for the lost limb, the prosthesis is more easily accepted by the body, and the phantom pain goes away.	makers, health personnel and patients. Patient participation is not mentioned.
MERIDIAN (Micro and Nano Engineered Bi-Directional Carbon Interfaces for Advanced Peripheral Nervous System Prosthetics and Hybrid Bionics) https://cordis.europa.eu/project/id/280778/reporting	Executive Summary: Meridian has developed novel interfacing technologies for peripheral nerve system (PNS) prosthetic devices by exploring the potential of nano-crystalline diamond thin films, prepared by plasma enhanced chemical vapor deposition, and innovative type of neuron engulfing electrodes. Diamond is ultimately biocompatible and chemically stable, opening up exploration of chronic prosthetic devices, improvement of voluntary control artificial limbs and artificial devices for neuro-regenerative strategies.	Patient participation is not mentioned.

COMPARISON 2

Data base used:

Google search engine

Scope of the comparison:

The search terms used were "3d printing and prosthesis and patient participation", as well as "3d printing and patients" and "3d prosthesis and patient participation", which produced more than 900 thousand results. Reviewing the first 50 results, it became clear that the focus of the search was on the prosthesis and to a lesser extent on the role of the patients, however around three interesting current projects were found among the 50.

Results of the comparison:

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The projects that the search had identified, dealt with 'quality of live' of the patient as a synonym for 'patient satisfaction'. The satisfaction is often measured by the declaration of the patients and the functioning of the prothesis. Two projects stood out: e-Nable and INK plant. E-nable is a not-for- profit private helping initiative which provides 3 d printing prosthesis to low-income households around the world. Over 100 makers participate in the initiative. Although patient participation was not declared as a feature of the creation or production process, the testimonials are full of examples of personal implication of the makers in finding and attending the people in need of prosthesis.

The project INKplant instead is not a project about 3d prosthesis, but rather about 3d implants (teeth, knees, etc.), however it is an interesting example of interdisciplinary approach between technological sciences and social sciences. INK plant takes into account a gender mainstreaming approach by selecting and using materials or processes not only tested on males and designed for male patients, but for the needs of female users. Also, a personalized approach to patient treatment is chosen, while it is not explained to which extent that implies active patient participation.

Conclusion of the search:

Just as in the first search, the conclusion is that the project DEEP is designed in a much more encompassing and complete way, when it comes to patients participation and the role of patients throughout the production process of the prosthesis. Again, DEEP has chosen an comparatively more holistic approach in that it has an implicit participation of patients and takes into account that the process of interpersonal communication and relation building is to be an integral part of the production of prosthesis. Thus, an interdisciplinary approach is guaranteed.

Search resluts:

Title description	Goal, results	Level of comparison with Project DEEP
E-Nable http://enablingthefuture.org/faqs/	e-NABLE is a global network of volunteers who are using their 3D printers, design skills, and personal time to create free 3D printed prosthetic hands for those in need – with the goal of providing them to underserved	There is no specific approach documented that would promote specific participation or communicational or motivational skills on behalf of makers or health

	populations around the world. e-NABLE is not a comercial endeavour, since it does not sell the devices. Rather it describes itself as a “movement” because there is no single legal entity or organization that represents it. In 6 years, e-NABLE has evolved from a small group of pioneers into a loose unofficial confederation of over 140 chapters around the world.	professionals. However, as the Project is a voluntary helping action of makers for users, the personal implication, communication and participation level can be assumed to be high.
European Network of Living Labs https://unalab.eu/en/project-partners/enoll	The European Network of Living Labs (ENoLL) is a global network of open innovation ecosystems (Living Labs) that places people at the centre of product and service development and innovation. The network and its members provide innovation services for small and medium-sized international companies, the public sector, organisations and citizens. ENoLL promotes the development of business and industry and the creation of tax revenue and jobs. The ENoLL international non-profit association,	ENoLL is the European umbrella organization to which a Living Lab of the universitat Autònoma de Barcelona belongs. The Living Lab of the UAB is an associated partner in DEEP and is one of the participants of the expert training in the part of Training of Trainers. It can be saidm that ENoLL until now maintains a focus on the technological

	as the legal representative entity of the network, was founded in 2010 and is headquartered in Brussels. ENoLL supports the evolution and the uptake of the Living Lab paradigm throughout Europe and worldwide, contributes to the creation of a dynamic, multi-layer and multidimensional European Innovation Ecosystem, and facilitates the cooperation and the exploitation of synergies between its members and external stakeholders. ENoLL has recognised nearly 400 living labs from around the world maintained by municipalities, universities, regions and companies acting also as the development and piloting partners.	aspects of 3 d printing, but has shown openness for an incorporation of new (social) aspects.
INK Plant, EU Project https://www.inkplant.eu/project	"The vision of INKplant is the combination of different biomaterials, high-resolution additive manufacturing technologies, and advanced simulation and biological evaluation, to bring a new solution for the fabrication of	INK Plant is not a project about prosthesis, however, it shows ways to integrate social criteria into a technology Project in a interdisciplinary way. Still, the "treatment of patients" seems a

	biomimetic implants for tissue regeneration. INKplant addresses the complexity of regenerating different tissues in the body and has the potential to reduce healthcare costs and rehabilitation time." "Gender-Specific Most studies in tissue engineering don't plan experiments for understanding gender-specific issues, and most in vivo animal models used in biomedical research are male, for simplicity and to avoid hormonal variations. INKplant methodically addresses gender-specific issues, fundamental in osteoarticular, bone, chondral, and mandibular repair and regeneration strategies. The project will analyze these procedures, perform specific experiments for considering gender and provide guidelines for researchers." "Long Term Sustainability solutions: Thanks to covering the whole implant development life-	more traditional way of looking at the relation between users and makers or health professionals. In this regard, The Project DEEP goes a step further and aims at "co-creation", "participación" and "prosocial communication" as some of the expected features in the relations of patients and makers. The fact that INKplant includes gender aspects in the selection of materials and processes, can be seen as trendsetting and may inspire some of the aspects dealt with in DEEP.

	cycle, from materials and technologies to patients treated in personalized ways, INKplant will contribute to configuring the EU hospitals of the future."	

3.2 Innovative projects on 3D printing and disabled people as co-designers

The number of projects combining 3D printing and disability are growing, given the characteristics of the medium. In fact, 3D printing ensures the design and implementation of technical tools that are more economical in terms of time and cost of materials and customization. Some examples of successful projects include:

- TypeCase (Dougie Mann), a 3D-printed keyboard built into the phone consisting of just five keys located on the sides of the smartphone to make them accessible with the fingers of the hand. In addition, the keys make it possible for the subject to "feel" text through small vibrations;
- Sonova has created custom, patient-tailored in-ear and BTE hearing aids through the use of 3D printing;
- Moorfields Eye Hospital has made the first 3D printed eye prosthesis using a machine from Fit AG;
- Layer, a London-based design agency, unveiled at Clerkenwell Design Week the first wheelchair (Go wheelchair) created based on the measurements of a patient's entire body;
- Ikea has created a line of products, called ThisAble, that includes 3D-printed furniture extensions that can be attached to cabinets, sofas or shower curtains to make daily life easier for people with disabilities;
- UNYQ, a company from the United States, offers custom non-invasive orthopaedic devices to improve the quality of life for people with various disabilities. Among other projects, they have 3D printed a lightweight, breathable and fashionable brace for people suffering from scoliosis;
- TOM and MakerBot have created several prototypes to make daily life easier for people with disabilities, such as Grabber, a cane that allows people to move objects with their mouths or limbs limited in movement;

Carry Crutches, a self-stabilizing cup holder for crutches; and IEat, an autonomous feeder designed for those with limited hand control who have difficulty eating on their own;

- The TogetherToGo (TOG) Foundation in Milan has created braces that help children with brain disorders move better by using 3D printing;
- +Lab (a laboratory of the Polytechnic of Milan) has created a project called '+Tuo' oriented to simplify the life of people suffering from rheumatoid arthritis, which has involved the creation of three unique products: a stopper-opener, a hinge-opener and a spoon holder.

Specifically, we will focus on good practices born in Italy.

The TogetherToGo Onlus Foundation (TOG) is a reference centre for disabilities affecting children and young people, a city of fragility where families will have the services they need at their disposal free of charge: a comprehensive care that includes rehabilitation, accompaniment in the school path, preparation for professional and independent life of their children, aiming at reaching their maximum potential. The Foundation was created in 2011 and aims primarily to rehabilitate children with complex neurological injuries, childhood brain injuries and genetic syndromes with mental retardation. In fact, the non-profit cultural association, chaired by Chef Carlo Cracco, which for over ten years has been promoting in Italy and abroad the future generations of Italian catering and the agri-food products of the Lombardy region, will be responsible for vocational training and job placement of TOG's children.

One of the aspects of the rehabilitation of neurolesioned children has to do with the creation of aids that allow them to overcome contractures and deformities, problems related to neurological injuries, as the brain organization, muscles and tendon structures are injured. Prior to the use of the 3D printer, orthopaedic aids were made exclusively from plaster, a heavy, malleable material with little aesthetic impact. The aids were standardized, rather expensive and, therefore, not replaceable with the speed that the growth of children requires. For this reason, the Foundation's objective has become to use 3D printers to build aids that are perfectly calibrated to the child, obtained with specific positioning of the body parts involved, light and aesthetically pleasing, inexpensive and quickly replaceable when the child grows and finds new difficulties.

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The procedure of developing aids with 3D printing is done through the following steps:

- The plaster: the first phase, the making of the plaster, is very delicate, the cast must be as precise and as comfortable as possible. After modelling the plaster on the patient, the therapists strive to file down as much as possible the areas that are not smooth or precise; so as to facilitate the scanner phase;
- Scanner and 3D modelling: the next phase is characterized by the scanning of the plaster and 3D modelling using appropriate software;
- 3D printing: after finishing the scanner, the last step is to print the saved file. The aids of this type are printed in 3d within 20h.

To finance the project TOG in 2014 participated in a contest organized by AXA, called "Born to Protect", thanks to which it was able to purchase two 3D printers, the programs for design and printing materials. Initially, TOG digitized and 3D printed small showers to ensure babies' correct posture, molded seats to ensure they sit in a way that protects their joints, splints that combat the intrusion of a plegic little hand.

Subsequently, TOG partnered with a Digital Fabrication Lab, Open Dot, where design, digital technologies, and craftsmanship come together. The idea behind the project is the creation of low-cost individual objects designed and co-designed by multiple authors working together to meet the needs of the Foundation's children and teens ages 0-18. This project was called "The object that is not there" and was presented on February 22, 2016, the purpose is to allow the child the achievement of maximum autonomy, encouraging him, allowing the inclusion to social life through suitable tools, aesthetically beautiful and useful to his life. The path of the project is articulated on several fronts:

- the design of a software dedicated to TOG's clinical operators to allow the scanning and digitalization of the interested body part and the consequent creation of orthopaedic aids in which Open Dot's know-how supports TOG's medical experience and specific competences to develop kinesiological innovation;
- The re-design of objects, cognitive systems, games, daily living aids for young children with motor, cognitive, communicative and behavioural deficits to facilitate their activities and integration.

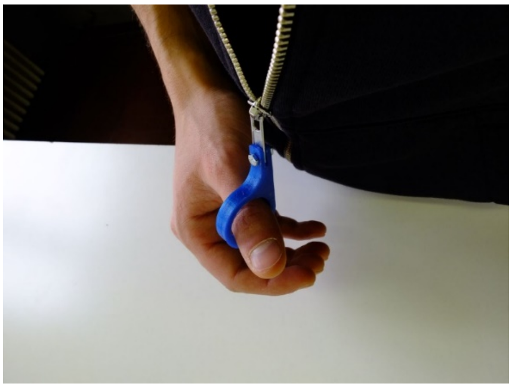
The objects developed in the project, for example, are pens or brushes that make it possible to write and draw despite difficulties in gripping a tool; cups or glasses that can be held even if one arm or hand is impaired; toys that can be used by children with limited communication skills; special positioning or locomotion objects that encourage integration with other children; cognitive rehabilitation tools that are made accessible even to very disabled children (Antonia Madella Noja, Secretary General of the TOG Foundation).

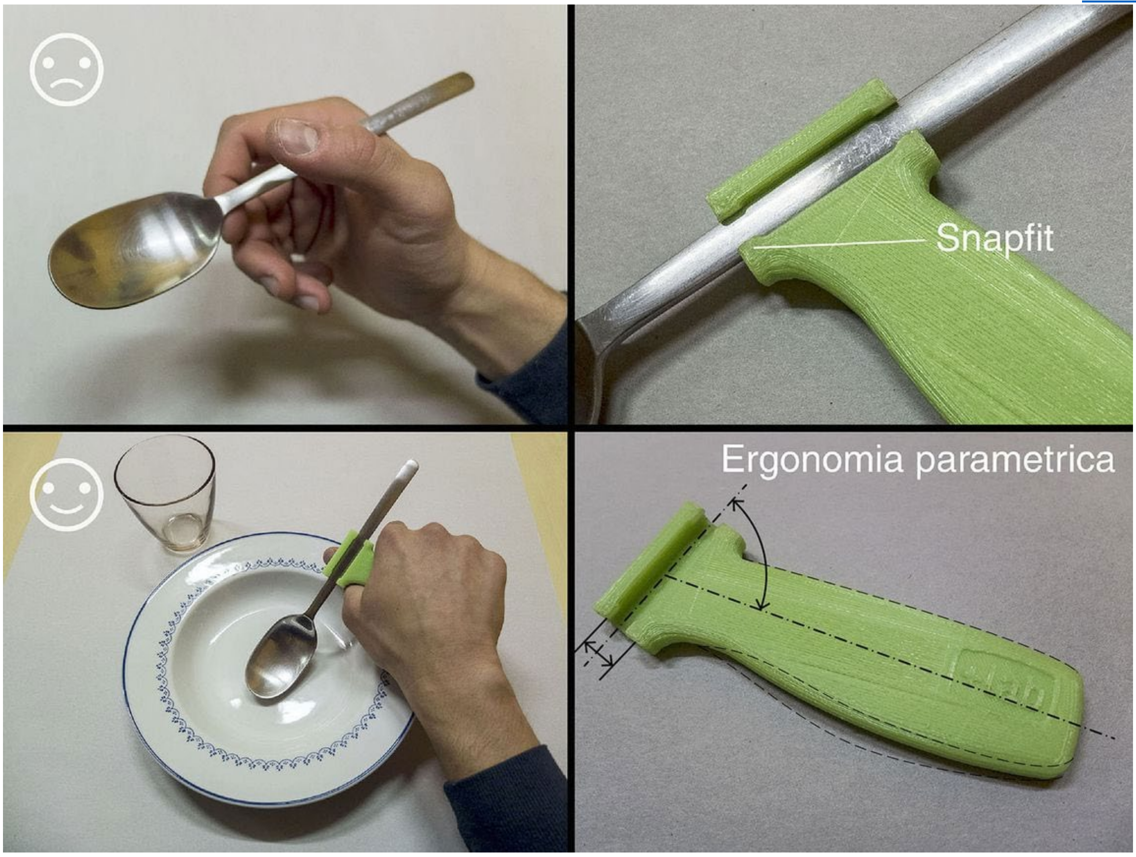
The Foundation's plans don't end there. TOG will expand by January 2023, hosting a therapeutic swimming pool in the basement, equipped with spaces and services designed for hydrotherapy, which integrates motor rehabilitation. On the ground floor there will be all the services also open to the territory: the Bistro, the areas for teaching and conferences, vocational training and school support and, finally, the FabLab. The latter is a laboratory for the design and implementation of aids and objects designed according to the specific needs and requirements of people with disabilities, which expands the activity already started successfully. Here there will be 3D printers with biological materials, coloured and customizable, an orthopaedic laboratory and a room with machines for digital woodworking. The design activities will always be carried out through the method of co-design, which involves collaboration between designers, makers, therapists, doctors and of course people with disabilities and their caregivers. The FabLab will also involve university students and professional institutes for the use of machines and the creation of prototypes and projects.
The entire first floor will be devoted to the rehabilitation center, with physiotherapy, speech therapy, psychomotricity, music therapy and cognitive therapies. New environments dedicated to technology will be created, such as eye tracking and the sensory room. There will also be an outpatient clinic with medical professionals and specialists to oversee all health aspects of the life of the child with disabilities.

The second noteworthy Italian initiative created by the +Lab is "+TUO".

The laboratory of the Polytechnic of Milan (+Lab) was born from the will of Marinella Levi, professor of Materials Engineering at Polimi. The idea of low cost 3D prints was introduced by a student of Design engineering as the theme of his thesis project and was later taken up again leading to the birth of the lab in 2013 and its new purpose: to create low cost digital technologies able to produce objects dedicated to people with disabilities. The lab started its activities in 2013 starting from a project oriented to simplify the life of people affected by rheumatoid arthritis who, in everyday life, have difficulties in performing most of the gestures, such as lowering a zipper or holding a cutlery. The project was called +Tuo and involved women who live the difficulties of the disease in the first person as "co-designers" asking them to collaborate actively in the creation of objects or assistive devices by expressing their needs and their problems. The term assistive devices refers mainly to small non-medical devices that help users during the execution of small daily activities (Interview with Marinella Levi of +Lab on SoundCloud)

In the article "+TUO project: low-cost 3D printers as helpful tool for small communities with rheumatic diseases" the lab described the steps and results of the pilot study of the project in the form of a case study with a small sample.



The general structure of the +TUO project is as follows:

1 Questionnaire:

- Questionnaire analysis; and
- Participant Recruitment.

2 Design of reference products.

3 Activation Phase.

4 Generative Session:

- Co-design phase (possibly repeated); and
- Co-production phase (possibly repeated)

The stakeholders involved were: end-users, designers, occupational therapists, and researchers in one cross-sectional team combining different skills and focusing on a common goal.

The questionnaires included questions about patients' daily activities, needs, and desires, with a focus on specific assistive devices they already use, highlighting the pros and cons for each. Participants were also asked to list any assistive devices they needed but had not yet adopted, explaining why they did not already have them. The reasons were generally related to high price, low availability, and low functional and aesthetic suitability.

The questionnaire helped researchers better understand end-users' needs, wants, and requests regarding particular activities/actions and specific assistive devices. Many activities (and related products) were listed as problematic, such as: climbing stairs, getting dressed, opening bottles or jars, tying shoes, performing general sports activities, putting on makeup, gardening, maintaining social activities, cooking, etc. The two most recurring activities were: opening bottles and zipping clothes or bags.

During the pilot study, two objects were created: a cup opener and a hinge opener. The starting point for the design was developed by the designers using the 3D computer-aided design (CAD) software SolidWorks, a useful software for creating solid models with a simple interface that helps designers make quick changes if and when needed. The first phase is the activation phase, a first collective meeting, where all stakeholders meet for the first time. The main goal is to introduce low-cost 3DP FDM technology, in this case, using the WASP project machine (www.wasproject.it). This first workshop is based on the belief that occupation-based practice uses occupation as both a therapeutic means and a goal of therapy (White et al., 2013). The activation phase aims to:

- Create a sense of community;
- Engage end users and include them in a social activity;
- Increase their awareness of the disease through discussion with other patients;
- Explain the operation, advantages, and disadvantages of low-cost 3DP.

As the questionnaire revealed, rheumatoid arthritis patients tend to lose their manual skills, which implies difficult active participation during the creation of models and mock ups made with more traditional prototyping techniques (i.e., hand modelling with simple materials). In this scenario, adopting 3DP for the prototyping phase was helpful in overcoming this barrier, as it required little manual skills. In addition, they used this first approach with end users to understand their opinion about low-cost 3DP and their ideas for possible applications, and explain the potential of this technology to end users. Next, a hands-on co-design exercise with 3D printers was conducted by the designers. This introduced the technology to all participants, showing them a simple case study choosing the zip-aid as a reference product. Each participant was then asked to consider and modify the reference product, to make it more personal and functional. Together, end users, OTs, and designers modified geometric, dimensional, and aesthetic aspects to achieve a fully customized product. At this point, the designer modelled the custom zip-aid, sharing the process with all other stakeholders making the file ready to be 3D printed.

After that, the generation phase took place. During this phase, assistive devices were made starting from design to production. This session is divided into two main phases: co-design and co-production. Co-design is an iterative process of ideation-prototype-testing that must be repeated as many times as necessary to achieve a product that is satisfactory to all. Generally speaking, during the co-design phase, the main objective is to define the functional aspects of the device such as: geometry, dimensions, proportions, weight, etc. The second phase of the generative session is the co-production phase. During this phase the attention is focused on the definition of aesthetic variables such as: color, texture, small decorations, considering also all the variables related to the printing process (printing speed, object orientation, etc).

The goal of the +TUO pilot study was to explore the advantages and limitations of introducing low-cost 3DP to co-design and co-produce assistive devices, along with and for people with rheumatoid arthritis. The objective was, therefore, the creation and validation of the +TUO design process, along with the interpretation of the first results obtained. The adoption of low-cost 3DP in this context has been positive both from a physical and occupational point of view. In fact, the collective generative process supported by the technology itself and investigated through +TUO, helped end-users to become part of a small community, to share ideas, problems and materialize customized solutions in a fast, dynamic and local environment. Moreover, in an inclusive perspective, different actors were involved and contributed with their personal skills and expertise, making the project dynamic and achieving functional solutions.

+TUO was then developed and implemented, resulting in the creation of three unique items created following the directives of women with rheumatoid arthritis: a cup opener, a hinge opener, and a spoon stand.

All products have the characteristic of giving more value to the strength that is in the hands. Some were designed with even the differences between each individual hand in mind. Specifically, the zipper opener was created with objects of different shapes in mind that hook into the ring of the zipper, allowing you to open the zipper without making the classic oppositional movement of thumb and forefinger, which is often difficult.

At the base of each project of the laboratory there is one constant: the collaboration with those who live first-hand the problems related to disability.

Having achieved positive results, the lab implemented new projects and supports.

For example, responding to the needs that Laura, a seventeen year old blind girl, brought to light, +Lab created the project "Notes between the fingers" reproducing an embossed score to try to solve the difficulty that visually impaired and blind people encounter in reading music in Braille.

In addition, +Lab has built further products for the visually impaired and blind such as: the card holder for role-playing games and the bread holder, which allows you to spread jam on a slice without getting dirty. These supports, in an unexpected way, have also proved useful for children.

Finally, the lab realized the DIYJ project, focusing on the joining of objects, the basic structural element of any system composed of many parts that is often neglected. Thanks to a deep analysis of the context, it became clear that the self-production of furniture, in particular the need to have a joining system for specific parts studied here, corresponds to the new demands to be met (https://piulab.it/)

References.

+Lab site: https://piulab.it/

Fondazione TogetherToGo site: https://fondazionetog.org/

Griffo, Giampiero, et al. "Moving towards ICF use for monitoring the UN Convention on the rights of persons with disabilities: the Italian experience." Disability and Rehabilitation 31.sup1 (2009): S74-S77.

Intervista a Marinella Levi di +Lab su SoundCloud: https://soundcloud.com/milly-barba/intervista-a-marinella-levi-di-lab

Ostuzzi, Francesca, et al. "+ TUO project: low cost 3D printers as helpful tool for small communities with rheumatic diseases." Rapid Prototyping Journal (2015).

4. Existing training materials on the topic of disability and 3D printing

3D printers are becoming technically and financially affordable: they offer the possibility of bringing new topics into teaching, as well as more comfortable and clear classical teaching.
To develop this paragraph we decided to go forward based on a study of the University of Maryland and to give some recommendation regarding the 3D printing.

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4.1 Inclusion and Education: 3D Printing for Integrated Classrooms (Study of University of Maryland, USA

The physical affordances of 3D printed objects have made this technology a popular medium for tactile learning aids. Current research has explored applications of 3D printed graphics for students with visual impairments. Brown and Hurst presented VizTouch, an automated tool for generating 3D printable line graphs in the context of math education. More recently, Braier, et al wrote about the potential to provide inclusive education with 3D printed graphics and presented their own implementation of software to automate the creation of 3D printable tactile aids. Similarly, Kane and Bigham [14] wrote about the use of 3D printed information as a tool for computer science education and STEM encouragement for youth with visual impairments. These works focus largely on generating 3D prints on behalf of populations with disabilities.
The direct use of 3D printers by people with disabilities is also a growing area of interest. Buehler, et al described the uses and pitfalls of 3D printers in special education schools [6]. In a more general exploration of fabrication techniques for Do-It-Yourself assistive technology, Hook, et al presented challenges for youth with disabilities in creating 3D printed AT devices. Also exploring 3D printable AT, Buehler, et al uncovered that a minority population of designers with disabilities sharing their DIY-AT on the website Thingiverse.
Working directly with students with ID, we are able to gain further insights into how people with disabilities can learn and leverage 3D printing technology in their education and daily lives. In addition to its popularity as both a novel and novelty technology, 3D printing can also be a means to self-employment. Some of the processes involved in 3D printing are translatable to similar manufacturing processes that require abilities like inventory stocking and tracking, receiving and processing customer orders, and following step-by-step instructions. Employability is a major goal and we believe that these peripheral benefits of 3D printing make it an appropriate technology for our participants to learn.

Modeling Teaching Strategies

They identified several strategies used by educators while teaching 3D printing, including easy start-up projects for a positive introduction to design and providing detailed instructions for more complex projects. The educators also noted differences in how youth engaged in design depending on whether they were required to complete specific design projects or allowed to engage in freeform object design

The educators reported that the most important technique for teaching 3D printing to youth was setting up success right from the start. Participants described a need to protect youth from failure especially during the early stages of learning. They also suggested that step-by-step instructions could create obstacles and induce frustration. Educators who let their students engage in more open-ended design assignments also made more references to perceived student excitement. We were warned, however,

that open-ended lessons may be more engaging, but can be difficult to manage with added students and requirements.
Based on these experiences, we created a mix of open-ended and structured lessons. While our students were frequently charged with the creative design aspects, we also provided structure in terms of planning exercises and requirements for each project.

Strategies to Support Learning

Four major strategies to instruction were used during the course of this pilot study: 1) journaling, 2) teaching for recognition through the use of instructional and memory aids, 3) using video instructions to help explain multi-step tasks, and 4) planning for problems in advance through preparation.

Jorunaling experiences

Both the lab intern and the researcher kept journals during the semester. Journal entries were written during the final 30 minutes of each session and consisted of a brief summary of what was learned during the day. Both journals were used to track progress and inform future lesson plans. Journal entries did not provide a firm indication of what content the intern would be able to remember from session to session, but the information captured did suggest that some days of instruction were more effective than others and this helped the researcher identify what information should be reviewed at the beginning of the next session.

Teaching for Recognition and Not Recall

The intern and the researcher created instructional and memory aids, including short written directions and slide shows with vocabulary guides. The medium of slide shows was selected to accommodate the learning preferences of the intern who preferred limited reading. Instructions were created as numbered lists with pictures depicting steps as needed. Each slide typically contained a vocabulary term on the top of the page and an illustration. By looking at the image, the intern was able to remember information about the associated vocabulary term. The intern had a hand in creating all of his instructional aids.
All of the slide content was either handpicked or created by the intern. The researcher assisted primarily with spelling and formatting content. These materials were reviewed once in the beginning of each session and again at the end of the session. In the event that the intern had difficultly remembering a term or concept, they would pause to review the related slides.

Videos as instructions

To help break up the three-hour sessions, the intern and researcher occasionally watched videos on YouTube. These videos helped keep the intern engaged and they also helped to reinforce the steps to complex task, such as printer calibration. The videos were a successful way for the intern to gain familiarity with the steps involved in these tasks before attempting them himself. We found the videos made by Printrbot to

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be exceptionally helpful because they were sufficiently detailed, but still brief and they covered important topics including setup, calibration, and extrusion.

Planning for problems in advance

While 3D printing technology is advancing rapidly, the printers are not always reliable and often require troubleshooting. An example of a common printer problem is build plate adhesion— this is problem with the 3D object lifting away from the printer surface before it is complete. Printer failures such as this one can delay the printing process and cause frustration. We identified a need to plan ahead for these types of technical failures. This was addressed in two ways: 1) the inclusion of instructions that could be followed if a failure condition was met; and 2) via repetition that reinforced troubleshooting behaviors. Both techniques helped the intern decide how to react in negative situations rather than getting stuck, and these techniques helped to facilitate problemsolving skills that could be applied to other scenarios.

Classroom Setup

The class met three times per week for two 50-minute sessions followed by a 2-hour lab at the end of the week. Students met in a lab with all of the resources necessary to design and print objects. Based on the experiences described to us by the 3D print educators we interviewed and the success of our case study, we chose Tinkercad for the design software and we purchased six Printrbot Simple Metal printers. Students were encouraged to use the lab computers, but several installed modeling and printing software on their personal laptops. Course information was disseminated through an outward facing website which students could easily access from home.

Course design

A goal for the first three sessions was to encourage students to get to know each other and form teams. To this end, the instructors paired off undergraduate students with young adults with ID based on common interests that the students mentioned during icebreaking exercises. The purpose of these small teams was to replicate the one-on-one advantages identified in our pilot case study, including building a rapport and familiarity between the students. Weekly lessons covered a brief history of 3D printing, the parts and maintenance of Printrbot Simple Metal printers, tutorials on the Tinkercad modeling software, product design, development, and marketing. Each topic was introduced for a full class period (50-minutes) followed by brief instructions and assignments in subsequent lessons. Students completed inclass tutorials, took part in discussion, and completed daily journals. In addition to daily journal entries, students completed four assignments and two projects during the semester. Journal entries provided students with an opportunity to reflect on what they learned and to work on their writing skills on a regular basis. Assignments were narrow in scope and typically focused on only developing one or two skills, but projects required students to use everything that they had learn during the semester.

Assignment 1 required students to write a short autobiographical sketch. This was an extension of the icebreaker activities and also served as a means for the instructors to evaluate each student's comfort level using a computer and cloud-based file storage. Assignment 2 required students to compile a list of items from Thingiverse that they would like to print for themselves or for someone they knew. This allowed the students to familiarize themselves with the existing 3D models and served as an introduction to Creative Commons Licensing5 , which dictates how created works can be used. Understanding Creative Commons is both a digital literacy concept and important for the entrepreneurial portion of the course. Additionally, the designs students selected were later used in an affinity diagramming (Figure 4) session to help students consider what types of objects might be marketable in preparation for their next assignment.
Assignment 3 required students to sketch out a product design, create the 3D model in Tinkercad (Figure 3B), and then write an accompanying product description. This exercise targeted skills related to creativity, design, and marketing.
Assignment 4 asked students to create an invoice form that could be used to collect customer information and order details from potential clients. With this assignment, students worked on skills related to finance, customer service, and planning by taking into account production costs, client needs and specifications, and the time necessary to design and manufacture a 3D-printed product.
Project 1 required the creation of an instruction manual with explanations of how to log in to Tinkercad, use Cura to print 3D models, and how to calibrate a Printrbot. Only one set of instructions was created per group and the completion of this assignment required both communication and writing skills.
Project 2 tasked students with the creation of their own line of products that could be sold to potential customers. This project was a cumulative assignment, and it required students to use the skills that they developed throughout the semester to create three design concepts, of which they had to select two to implement as 3D models. Of the two models, one was printed (Figure 3A) and used in a class presentation to pitch their product line.

Motivation, Outside Factors, and Attendance

While UG students would grudgingly get on board for classwork, it was more difficult to motivate the students with ID and sometimes this could not be accomplished at all inside the 50- minute class period. Sources of disengagement that we observed within the classroom included completing repetitive tasks, struggles with printer failure, and issues of personal pacing. UG4 would occasionally lose interest and start playing with his phone or browsing the Internet while his partner completed tasks. There was one instance where UG6 became noticeably upset because two prints had failed during one class period. Absenteeism was another big issue. Many of our students with ID travel significant distances to arrive on campus and a harsh winter causing school closures and dependence on family members for rides during inclement weather colluded in severely limited attendance. UG students missed class less frequently, but their absences caused more disruption. Without the UG students, students with ID who counted on their partners for reminders or support during assignments would sometimes shut down. We, as instructors, were available to help these students, but we did not

have the close bonds with these students that they had with student peers and so our guidance was not always received with enthusiasm.
We tried to mitigate issues of motivation by offering short, medium, and long-term rewards both inside and outside of class time. A short-term reward might be allowing a student to pick the music in the lab if they progress through two or three steps in an assignment. This method was frequently used with ID6 who often came to class disengaged. An example of a medium-term reward was allowing the student to choose a 3D model that could be printed during class time and giving it to them as a reward for meeting their goals by the end of the session. A long-term reward that was more popular with the UG students than the ID students was the option to come into the lab for free time where they could use the printers for extended prints and projects outside the scope of the course. UG4 in particular was interested in gaining access to other types of 3D printers and would occasionally stay after class to learn additional information. We found that these strategies helped to keep students motivated.

Collaborative Problem-Solving

A benefit of the structure of integrated classroom setting was that ID and UG students alike had access to multiple resources to aid them when working through a problem. This included partners, peers in other groups, as well as the course instructors. Students regularly consulted with their partners and with other students in the course before asking for help from the instructors. These student explanations in combination with instructional materials supported universal design for learning by providing multiple mediums and multiple explanations of concepts. For students helping to answer questions, this also provided the opportunity to develop their communication skills.

4.2 Some Recommendation to train on 3D printing

It should be borne in mind that if there are many cases of good practice. here is no comprehensive list. We will try to at least indicate some possible directions of use, without aiming for the complexity of such a list.

1. Printing of models and aids. It often happens that the teacher needs a tool, does not have it available or needs to create a simple three-dimensional model. It can be purchased, but the problem can be both price and delivery time. Such an artifact usually cannot be available until the next day. For example, if it decides to learn about a "nitrogen catastrophe", it needs a nitrogen model. The carbon in the collections is useless. In this case, printing seems to be the ideal choice.

2. Aids can appear in front of students. It is a task to give the printer after you discuss the problem with a very interesting and most importantly you need what you actually need. The process of creating an instrument right in front of their eyes can play a positive motivational role (although they quickly get used to regular performances).

3. Creation of accessories for kits. There are a large number of technical kits in schools, into which new parts can be added with the help of 3D printers, which would expand their use. There are a large number of ready-made models available, but of course you can create your own.

4. With the help of a 3D printer, the connection between art education and informatics can be fundamentally innovated. Students can create 3D models, which are then printed, so working with 3D tools for students takes on a whole new dimension.

5. Working with 3D objects and printing them can be an interesting element for improving technical education. Students can be taught to design individual components and to create various constructions on a 3D printer and lead them to an understanding of their functionality (eg that the I profile is stronger than straight).

6. With the help of 3D models, it is possible to make teaching more illustrative in many respects. For example, you can print models of the footings of ancient columns or other architectural elements that will lead to a better understanding of some contexts and a clearer idea of what the element looked like and what it was used for.

7. Directly 3D printer can be used with accessories to teach 3D printing and all related technologies - modeling, rendering, basic construction, work in CAD, etc. It can thus serve as an interesting technical practice, which, for example, expands the range of optional subjects and gives students completely different experiences and competencies than their peers.

8. 3D printers are often used to print spare parts and components that break. It is a relatively versatile but abundant use.

9. A RepRap 3D printer can be used to teach how to set up 3D printers and similar devices. It can lead students to develop technical thinking, teach them the basics of mounting and soldering, or connecting the printer to a computer.

10. Printing personalized rewards is one of the most rewarding things you can do with a 3D printer. It is thus possible to create, for example, birthday gifts, rewards for students with honors, all tailored and personalized. The price of individual gifts is usually around crown units and the students are happy about them.

Of course, you can imagine a number of other activities for which the printer can be used. It always depends mainly on the specific school climate and the possibilities that are given by the chosen printer and the mode in which the facility works at the school.

How to create models?

An interesting question is in which tool to create models for 3D printing. First of all, it is necessary to be clear whether it is primarily a practical activity that leads to the printing

of an artifact, or whether we need to learn students to work with 3D modeling or the basics of design.
Probably the best and best set of tools is free for students and teachers from Autodesk. AutoCAD is available (including all extension modules, so it can also be used for driving schools or for maps or city designs). The control is not very intuitive and simple, but on the other hand it is a professional tool, which they will undoubtedly encounter as students of technical fields or graphic artists or animators. However, working with AutoCAD for students will require a longer, ideally year-round seminar.
3ds Max and 3ds Max studio also come from the same workshop. It is more intuitive and designed especially for graphics and designers, leaving some technical knowledge and skills.
SketchUP is very popular for teaching 3D objects in a school environment. It also exists in the Make version, which is designed for primary and secondary education. The application was not originally designed for designing models for a 3D printer, but is generally used for quick design of 3D models of houses, apartments or things. The advantage is a simple environment and good connections with art subjects.
Open source Blender is a complex, robust environment for creating 3D scenes and their eventual animation, so you can also create a movie in it, for example. However, it is more suitable for working with 3D printing as a good converter between formats or at a time when the teacher has the ambition to lead students to create animated films or more demanding constructions.
But there are also online tools for simple modeling, such as TinkerCAD. It is very simple and allows you to create 3D objects from individual components. Thanks to its simple operation, it can easily be used to develop the spatial imagination of students in the second stage of primary schools. Another advantage is that no installation is required. It is ideal for teaching in a few hours, students do most of the tasks relatively quickly. An alternative to this tool is, for example, Shapesmith.

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Conclusion

The State of the Art produced thanks to the complementary work of the DEEP partnership has allowed us to reflect on some important aspects concerning both the specific issue of disability and the way in which this topic applies to the world of 3d printing.

The historical, social and therefore also legislative evolution is mainly expressed in the terminological changes: from "integration" to "inclusion".

The term "integration" is understood as a guarantee of respect for rights within ordinary places, without, however, modifying the rules and principles of functioning of society and of the institutions that welcome persons with disabilities. Behind this approach there is still a reading based on the medical model of disability (these people are "sick", "disabled", "limited" and must be protected on the basis of "special intervention", such as the support teacher). In short, the idea that people with disabilities are "special" and should be supported through mainly technical interventions prevails. Integration, therefore, is not a full recognition of dignity and legitimacy, so much so that it is based on available economic resources and is therefore subject to parameters outside the law.

Inclusion, on the other hand, is the concept that prevails in the most recent international documents and on the basis of which the person with a disability is considered a full citizen and therefore has rights like everyone else. It is also recognized that society has organized itself in such a way as to create obstacles, barriers and

discrimination, which must be removed and transformed. The person with a disability, therefore, enters the community with full powers, has the right to participate in choices about how society is organized, its rules and principles of operation, which must be rewritten on the basis of all members of society. In short, people with disabilities are no longer "guests in society", but an integral part of it, active and participating citizens (G. Griffo, 2009). The transition is not only a terminological change, but an innovation in concept and institutional setting. The objective is to place at the center of the school the value of diversity, as an opportunity for growth given by the interaction with a person with disabilities or other types of disorders, which can also be transient.
Inclusion has been achieved thanks to a long series of interventions of a socio-psycho-pedagogical nature that are listed below: personal aid services, removal of architectural barriers, the right to information and the right to study, adaptation of equipment and personnel of educational, sports, leisure and social services, full integration into the world of work, total accessibility of public and private means of transport, foster care and placement with individuals and families, organization and support of housing communities, family homes and similar residential services, establishment and adaptation of social rehabilitation and educational day centres, organization and implementation of extracurricular activities.

The use of 3D printers now makes it possible to adapt, customize or even create more effective aids right from the start, improving quality of life of people with physical or cognitive disabilities in respect of unique needs.
DEEP recognizes the importance that
today, these technologies cover, placing them at the centre of their model and, in order to exploit their potential to the fullest, the inserts in a perspective of sharing and multidisciplinary training.
As explained in this document, the most recent studies show that up to one third of aids are not used by the disabled today (Scherer 2002, Federici and Borsci 2014). The use of 3D printing, which places the disabled at the centre of the production process of their aid, united to the use of the motivational and prosocial approach by professionals who will come into contact for various reasons with people with disabilities, it will favour a cognitive, emotional and attitudinal change in people with disabilities.
Therefore it can be stated that the Project DEEP has chosen an comparatively more holistic approach in that it has an implicit participation of patients and takes into account that the process of interpersonal communication and relation building is to be an integral part of the production of prosthesis. Thus, the psychosocial impact is built in component of DEEP and makes it more interdisciplinary in what concerns the socio-psycho-technological approach.