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Experimental Education of Collaborative Design. The Case of an Inclusive Bus Stop for a Tourist Transportation Hub*

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The design of transport infrastructures must be developed for social sustainability. Collective transport, interfaces and pedestrian infrastructures must guarantee a combination of quality characteristics, where accessibility according to the universal design approach is prominent. Universal and inclusive design must be consistent with user expectations and needs, and so, the associated process must involve people with disabilities and elderly citizens to understand their difficulties in using the built environment. This is the context of the research project Accessibility for All in Tourism (2017–2019), that focuses on the development of a pilot study of an accessible, smart and sustainable bus stop to be located at a tourist transportation hub. The research was developed considering the perspective of multiple users, professionals in the disability field, and experts who applied technical standards. This co-design process attended to different users' needs. It was a process that required a transdisciplinary approach by the team, integrating students and people with disabilities, walking and observing them and taking into account senior tourists' perceptions through an inquiry survey. This paper describes the collaborative approach that was developed with Civil Engineering students at the Institute of Engineering at the University of Algarve, influencing their work and knowledge. The results indicate that students perceived the concepts of universal design and inclusive design and designed the bus stop for social sustainability. An inclusive society requires input from different users of the built environment and knowledge of their specific needs by engineering designers. Pedestrian infrastructure and interface design demand user-centred approaches and so, processes of co-creation with communities.

Keywords: accessibility for all; co-design; bus stop; users; education; social responsibility; sustainability

1. Introduction

1.1 Sustainable Mobility

Traditional transport planning and management have been focused on motorized transport and speeding up traffic, mainly in relation to individual transport means. Decades of car-centred approaches had strong implications as the use of fossil energy is dominant and causes great environmental and health impacts, on every territorial scale. Nowadays, the perceived climate changes and the sustainability paradigm demand a low carbon mobility, i.e. environmental sustainable mobility.

Sustainability considers human development but in which the effects of human activities stay within certain limits, so as not to destroy the diversity, complexity and functions of the ecological system which serve as support to life [1]. This ecological perspective is intrinsically related with how natural resources are managed. According to Herman Daly [2] environmental sustainability has to satisfy three basic generic lines: (a) The rate of use of renewable resources does not exceed the rate of regeneration; (b) The rate of use of non-renewable resources does not exceed the rate at which substitutes are developed; (c) The rate of pollution does not exceed the assimilative capacity of the environment.

A changing of energy paradigm is needed which considers energy saving, through reduced demand, maximizes the use of renewable energy sources and uses fossil fuels in the cleanest possible way [3]. Ensuring that impacts of transport activities do not threaten environmental sustainability is an important criteria in sustainable mobility [4].

In consequence, the environmental dimension of sustainable mobility is focused on a low consumption of non-renewable natural resources which will contribute to better public and ecosystem health [5]. So, social and ecological dimensions are integrated in the broad concept of sustainable mobility.

Khan [6] describes social sustainability as "social factors that are essential for achieving long-term, social wellbeing". However, the concept must be broader, as Rosa [7] defends, social dimension of sustainability attends to specific objectives alluding to social equity, equal opportunities in the access of goods, services and information, and the active participation of all citizens in society. This perspective is in line with the Sustainable Development Goal 11: Making cities more inclusive, safe, resilient and sustainable [8].

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In consequence, sustainable mobility must contribute to social inclusion. Providing accessibility to basic transport (needs) and ensuring equal access to transport services (justice) are important criteria in sustainable mobility [4].

Achieving sustainable mobility requires the full involvement of professionals, stakeholders and society, i.e. it requires socially resilient communities that collectively adapt and self-organise to the required changes.

In the European Union, a diversity of measures has been promoted to attend sustainable mobility with emphasis on low carbon and zero emission vehicles, implementation of pedestrian and cycle infrastructure, public transport and their interfaces, car-sharing or pooling schemes, electric vehicles, mobility as a service and the associated digital technologies. According to Holden et al. [9] the most important grand narratives of sustainable mobility are low mobility societies, collective transport, and electromobility.

1.2 Design for Inclusive Mobility and Barrier-Free Built Environment

Public transportation systems are generally designed, worldwide, for a healthy population and rarely take into account the needs of people with disabilities [10].

All over the world, the importance of inclusive mobility and universal accessibility has been highlighted as factors and indicators of sustainable development of territories. In this context, a new culture of mobility [11, 12]. more focused on people, has been stimulated, triggering initiatives for a more sustainable urban mobility and more inclusive territories, without physical, social, and communicational barriers.

In Europe, the concept of "inclusive mobility" emerged in France and later in the United Kingdom (UK), trying to solve the problem of social exclusion in transportation. In France, the issue of the "right to transport" was raised in a law published in 1982, Loi d'orientation sur les transports intérieurs [13].

In the UK, in 1998, recognition of the link between social inclusion and mobility emerged with the Transport White Paper entitled "A new deal for transport: better for everyone" setting out the government's transport policy [14]. The priority was to promote the implementation of an integrated transport policy to contribute to a fairer and more inclusive policy.

In latter decades, European Institutions expressed their commitment to a "Barrier-Free Europe" [15]. Associated to this commitment emerges a new way of understanding the concept of "accessibility" according to the universal design approach.

Universal design aims to make the design and composition of different environments and products accessible and understandable, as well as usable by everyone, to the greatest extent, in the most independent manner possible and without the need to adapt design solutions [16]. Universal design is referred to in relation to the social dimension of sustainable development [17].

The pedestrian infrastructure is made up of sidewalks or other routes (usually, exclusively for pedestrians), road crossings and modal interface areas (pedestrians/collective transport, collective transport/collective transport, pedestrians/individual transport). In the requalification of these pedestrian spaces, universal accessibility has been considered as an additional attribute of the concept of walkability, usually associated with connectivity, legibility, comfort, convenience, attractiveness and conviviality, as presented in the project COST: Pedestrian Quality Needs [18].

Thus, public transport systems interfaces must be accessible for all, as this is one of the attributes of good transport services, essential for social inclusion purposes and for the improvement of quality of life of citizens in order to increase the utilization of public transport, contributing to environmentally sustainable mobility.

According to the European Concept for Accessibility Network (EuCAN), this "accessibility is the characteristic of an environment or object which enables everybody to enter into a relationship with, and make use of, that object or environment in a friendly, respectful and safe way" [19, p. 23]. It focuses on people with reduced mobility, such as people with disabilities (mobility, vision, hearing and cognitive dimensions), children and elderly people. Transport infrastructures and services must consider this equity attribute which is associated with social sustainability and inclusion.

This is an important social issue, concerning elderly people, too. The World Health Organization regards active ageing as a lifelong process shaped by several factors (e.g., transportation) that favour health, participation and security in older adult life [20]. It considers that an age-friendly city adapts its structures and services to be accessible and inclusive to older people with varying needs and capacities. Transportation is particularly important for older people to have access to urban facilities and services that could support active ageing. So, transportation, including accessible and affordable public transport, is a key factor influencing active ageing. In fact, elderly people have several reasons for not using public transportation: the difficulty of embarking and disembarking, the fear of travelling alone, poor staff service, the difficulty of getting a seat, scarcity of information and the price of travel [21].

From this perspective, active/healthy ageing stresses the importance of maintaining the autonomy and independence of the elderly for an increase in the quality of life and health, and transportation plays an important role in these attributes. Indeed, the elderly tend to have physical, intellectual and sensorial disabilities, they have special needs as people with disabilities or reduced mobility and so the universal design approach has to be considered within the curricula of all occupations working on the built environment.

Universal accessibility must be considered in transport vehicles, terminals and stops (interfaces), pedestrian infrastructures, architecture of buildings, information and communication technologies. The principles of the universal design must be considered because they guarantee (1) equitable use, (2) flexibility use, (3) simple and intuitive use, (4) perceptible information, (5) low physical effort, (6) tolerable for error, and (7) size and space for approach and use [16]. These principles are focused on attributes of the end result. Universal Design describes the qualities of a final design of a built environment or a product.

1.3 Participatory Design

Design process is changing in a context of sustainable, resilient, and inclusive communities.

Usually, sustainable design is associated with green design, a well-known concept that is, mainly, associated with the creation of buildings which are energy-and water-efficient, considering their long life, i.e., it is a concept that translates the environmental dimension of sustainability. However, although research on social sustainability is growing, the role of design is rarely discussed and so, the concept of design for social sustainability is not well-understood [22]. According to McMahon et al. [23] social sustainability in design considers human needs and wants whilst being cognisant of environmental limits, product responsibility, resource use and carrying capacities, paying due attention to traditions, engaging in dialogue, having equity in expressing ideas, compromise, self-fulfilment and altruism in design practice. So, the needs of people with reduced mobility must be known.

Traditionally, design was associated with expert knowledge and practices contained within a particular set of professionalized fields, such as industrial design, architecture and urban planning. In this perspective, decision-making was developed according to the point of view of designers and enterprises (paying clients). For example, civil engineers, in addition to their technical skills, have communication skills and interact with clients to find out their needs and relay that information to the design and construction teams [24]. However, while there might be good communications between designers and paying clients, both have a gap in their communications with the end user. [10]. In another way, design, engineering, and decision making in firms are led by people from the dominant social groups (e.g., male designers and engineers), and so product specifications are likely to centre around the needs of people who belong to those groups [25].

In northern Europe, in Norway, participatory design grew out of work beginning in the early 1970s with computer-system designers, which emphasized the importance of the user and the collaborative learning process with designers/planners [26]. To place the user at the heart of the design process, a designer needs to understand who the user is [27]. In fact, the scope of possible users and the complexities of human experience and identity is broad. Hays [28] proposed the ADDRESSING framework that can help designers understand there are different users depending on the combination of age, developmental and acquired disabilities, religion, ethnicity, socioeconomic status, sexual orientation, indigenous heritage, national origin, and gender.

An inclusive society requires input from different users of the built environment and knowledge of their specific needs. This highlights the need for participatory design, presently known as co-design.

Participation is a process through which people become involved, to some degree, in development processes. These approaches need specific tools that can be divided into four main categories (1) Group dynamics to guarantee active participation of stakeholders; (2) Visualization techniques to involve people with different academic backgrounds; (3) Interviewing and oral communication techniques to understand different points of view regarding people' s problems (semi-structured interviews); (4) Field observation techniques benefit useful information, from a group perception [28]. In fact, tools in participatory approaches are intended to facilitate the co-creation and co-design of products, services and processes. With brainstorming, active participants can come up with several solution ideas, presenting their needs and expectations.

A co-design process is a transparent process of value creation in ongoing, productive collaboration with, and supported by all relevant parties, with end-users playing a central role, covering all stages of a development process [29]. It is considered as a joint creation and evolution of value with individuals, intensified through platforms of engagements, and embodied in domains of experiences, expanding wealth-welfare-wellbeing [30]. Computer-supported collaborative learning is a field reference, since the 1980s [31].

Co-creation provides a way to connect products and spaces to consumers and users, and when inclusion is also considered, there may be greater potential to garner customer loyalty [26].

Disability rights and disability justice activists contributed to the triggering of participatory design processes by insisting with the slogan "nothing about us without us" in the 1980s and 1990s. In the last decade, design justice appeared and calls for equitable design processes and design outcomes [24].

1.4 Teaching Universal Design in Higher Education of Engineering

In the beginning of the 21st century, there were few examples of curriculum materials integrating the values of universal design into design courses, mainly in the disciplines of architecture, industrial design, interior design, landscape architecture and urban design [32]. In addition, experiences in engineering design, computer engineering, transportation engineering, and civil engineering have been taught considering the user-focused design of accessible technologies, vehicles and built environment. However, according to Bigelow, engineering curricula rarely include an emphasis on universal design principles [33].

The perceived importance of the rights of citizens with disabilities and the necessity of ensuring equal opportunities led the Council of Europe to propose the Resolution ResAP (2001)1 for the introduction of the principles of universal design into the curricula of all occupations working on the built environment, i.e. buildings, traffic provisions and places or spaces open to the public [34]. With this Resolution, social responsibility of professionals should be considered to make the built environment universally accessible to everyone, including persons with disabilities, people of all ages, sizes and abilities. So, cognitive, physical, and learning disabilities must be perceived by civil engineering students in the process of conceptual design.

Design is considered an essential element of civil engineering education and Engineering practice. This considers the entire design-to-completion process for buildings, roads, dams, bridges, water systems, and other major works. Civil engineers manage a range of projects encompassing transportation infrastructure, and so they are important actors in the development of sustainable and inclusive mobility. In addition to their technical and critical thinking skills, civil engineers have communication skills and, usually, interact with clients to discover their needs and relay that information to the design and construction teams. However, presently, co-design processes demand good communications between designers, paying clients and final users. Education for sustainable development must consider these innovative approaches.

User led and centred design includes people with disabilities in the creation of new technology and inclusive spaces. These processes are considered in the teaching of different design courses. At the University of Dayton a design project has been implemented in a first-year engineering design course in an effort to raise awareness of the need for engineers to be more inclusive when designing. Students were asked to apply universal design principles to redesign an engineering laboratory to make it more usable to all, including individuals with disabilities who use the room. In this teaching process, university's disability services staff and individuals with first-hand experience of disability, provided guidance to the class by serving as project mentors [33]. The Taskar Center for Accessible Technology, housed by the Paul G. Allen School for Computer Science & Engineering, at University of Washington, engages undergraduate design and engineering students in participatory design and inclusive design practices. The end-users are integrated into the design cycle, to allow them and caregivers to inform the design process, to encourage students' use of accessible best practices, and to promote the rapid creation of real, usable working prototypes [35].

Universal design has an important place in engineering design [24]. Human-centred design includes end-users in the design process [33]. So co-design for social sustainability can be strengthened in civil engineering education through Project-Based Learning which is considered one of the effective student-centered strategies in engineering education in many fields [36]. It is a learning-oriented methodology that provides students with the acquisition of critical knowledge, problem-solving proficiency, learning strategies and participation skills.

At the Institute of Engineering of the University of Algarve, the incorporation of the concept of "Accessibility for All", and the associated universal design's approach, into Civil Engineering's curricula, has been ongoing since 2001, in the Department of Civil Engineering, in the course unit of Roads and Streets [37, 38]. The focus was placed on transportation engineering curricula. This program was assumed in view of the social dimension of sustainability that considers social equity and an active participation of all citizens in society, as democracy requires, and so, professionals must act with ethical and social responsibility. Since then, students perform practical works on accessibility for all of the built environment, considering technical details of pedestrian routes, access to historical buildings, cultural equipment, transport terminals, bus stops, tourist agencies and hotel units. The first interactive experience with users was in 2007, when students had contacts with people with visual disabilities to understand the needs to consider in the design of some pedestrian infrastructure [39]. This public participation experience was integrated into the Sustainable Mobility Plan of the city of Faro (2007–2008).

This is the context of the research Project ACCES4ALL – Accessibility for All in Tourism (2017–2019), developed at the Engineering Institute of the University of Algarve. Its main objective was to develop a pilot study of an accessible, smart and sustainable bus stop to be located at Faro International Airport, in Algarve, Portugal. It focused on a standard urban bus with two doors (12m) and the corresponding bus stop (example of modal interface). Higher education students were integrated to develop scientific research and technological development activities based on experience or practice based research, oriented towards innovation in the inclusive design of products. So, a collaborative design approach was considered to increase the knowledge of user needs considering people with disabilities and elderly tourists. It was assumed that technical decision-making associated with the design process must include the perceptions of people with functional diversity.

The general goal of this paper is to present the experimental education of a collaborative design approach that was developed in the project ACCES4ALL and the active participation of Civil Engineering's students. The specific goal is to analyse if civil engineering students designed for social sustainability from this experimental education, through an appraisal of their proposed layout of an accessible bus stop.

2. Methodology of Collaborative Design and Practice Based Research

2.1 The Project ACCES4ALL

The main goal of the Project ACCES4ALL was to develop a pilot study of an accessible, smart and sustainable bus stop to be located in the most important transportation hub in Algarve, the Faro International Airport.

A collaborative approach was developed which considered different interconnected actions: contacts and workshops with institutions and enterprises; questionnaire-survey for elderly tourists at Faro Airport; walking and observing people with visual disability and people in wheelchairs in the city of Faro and at Faro Airport; a co-design process that involved the University of the Algarve team and students in the research which included multiple other participants (Fig. 1).

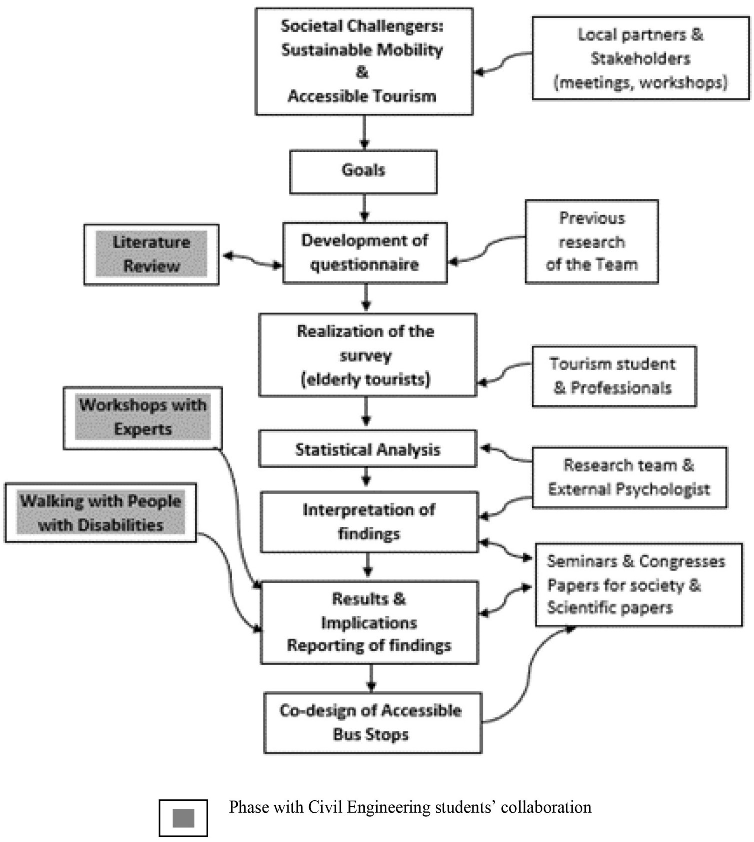

Fig. 1. Methodology of a co-design process of an accessible, smart and sustainable bus stop.

First the team worked in close coordination with regional and municipal entities and developed multilateral meetings and institutional workshops, mainly with municipalities, tourism enterprises, transportation enterprises, The Blind and Partially Sighted People Association. The involvement of these stakeholders was promoted and influenced the definition of societal challenges concerning sustainable and inclusive mobility in the Algarve, with the focus on tourist infrastructures.

Previous research of the team and the developed literature review facilitated an understanding that an accessible bus stop considers several attributes, namely: (a) urbanistic; (b) urban furniture (c) pavements and surfaces and (d) information and communication. The systemic character of these attributes was perceived as being directly or indirectly interrelated, and that these attributes may require specific technical differentials according to people's needs.

Meanwhile, there was a workshop with several stakeholders, a representative from The Blind and Partially Sighted People Association and invited architects. In this participation meeting all parties exchanged information about the universal accessibility of pedestrian infrastructures.

To understand the point of view of older people, a questionnaire-survey, for elderly tourists aged 60 or over, was developed at Faro International Airport. It considered four sets of questions: (1) information about the respondent; (2) characterization of their mobility where they live and where they were staying in the Algarve region (as tourists); (3) information on the perception and importance of universal accessibility conditions in bus stop environments; (4) use of information and communication systems and technologies.

In April and May 2018, a Tourism student performed the first 50 questionnaires with senior tourists at the Departures Concourse Area. In August and September 2018, inquiries were conducted randomly by professional inquirers, mainly in waiting areas before departure. During the survey the interviewers used photographs to explain technical aspects to elderly tourists.

Inquiries, totaling 851, produced considerable data that was introduced into an electronic file, using advanced statistical analysis capabilities of Statistical Product and Service Solutions (IBM SPSS, v.25).

Descriptive statistics of the frequency of each answer were created by the team and external psychologist volunteers, characterizing elderly tourists by age, gender, academic studies, mobility difficulties, perceived accessibility of bus stops in their countries. A chi-square test of independence was performed to assess the statistical significance in some relationship of variables.

In the meantime, a field survey was conducted by visiting the bus stop, proposed to be rehabilitated, at Faro International Airport. Universal accessibility conditions of the bus stop were analysed together with people with disabilities, technicians from the transportation enterprise and from the airport.

To understand the needs of people with disabilities, in terms of their mobility, observational methods were developed. Some outdoor visits to the city of Faro and the airport were undertaken to understand the mobility problems of people with visual disabilities and people in wheelchairs, some of them volunteer tourists.

Researchers and volunteers navigated together through the pedestrian networks located between the train station and the bus terminal. These pedestrians were observed while they navigated through the built environment. Researchers saw their behaviour at sidewalks, road crossings and bus stops. People with disabilities explained their difficulties, needs and expectations. Researchers recorded people's behaviour to understand, analyse and interpret the implications of their perception of the built environment.

Concerning the visit to Faro Airport, the same kind of participant observation was undertaken while travelling by bus, leaving the bus stop, using the bus stop, crossing the pedestrian crossing, navigating through the built environment of the airport – a large place with little legibility for the blind. As it was a sunny day, people with low vision had photophobia/light sensitivity problems when getting off the bus and leaving the buildings. Blind people had difficulties finding the MyWay point of contact to obtain assistance.

The interpretation of the results of the inquiries led to the need to integrate young psychologists on a voluntary basis. Final findings were considered in the layout of the proposed accessible bus stop located at the Faro Airport, an important tourist transportation hub.

2.2 Student Involvement

The design project experience was implemented in a third-year civil engineering course to raise awareness of the need for engineers to design for social sustainability, being more inclusive when designing. Students were asked to apply universal design principles and user' s needs to design an accessible bus stop, usable for all. Students were involved in the project throughout the 2nd semester of 2016/2017 and 2017/2018 academic years.

In the academic years 2016/2017 and 2017/2018, Civil Engineering students, in the Roads and Streets Syllabus, were involved in the bibliographic review of international normative literature about accessible built environment. Regarding the bus stop, the questions given by the main researcher were: (a) How high is the waiting platform in relation to the carriageway? (b) What type of kerb (shape) is used? (c) What is the slope of the access ramps from sidewalks to the waiting platform? (d) How wide is the waiting platform? (e) Where is the shelter positioned? (f) What are the needs of people with motor disabilities? (g) What are the needs of people with visual disabilities? What are the needs of elderly people? This problem definition phase was very enriching due to the exchanges generated between Portuguese students and Erasmus students from Spain, Poland and Brazil, creating diverse sources of knowledge.

In the 2018/2019 academic year, civil engineering students participated in a collaborative workshop, where researchers, a representative from The Blind and Partially Sighted People Association and invited municipal architects shared information about the universal accessibility of pedestrian infrastructures, providing guidance to the class.

To understand the point of view of older people, in this class, students received information from the Tourism student, who developed the first questionnaires, about the previous results of elderly tourists' needs.

These students were involved in the field survey of the bus stop, proposed to be rehabilitated, at Faro International Airport. They measured the bus stop and visited it together with people with disabilities. Technical accessibility guidelines were considered in this phase. They also saw the difficulty of a paraplegic engineer (consultant in this project) trying to get on a bus, without help, via a ramp with a 25% gradient (the ideal gradient is less than 6%). Some of them tried to use a wheelchair and experienced the difficulty in moving on unstable pavements and in sections of streets with a large longitudinal or cross steep slope. They navigated together with people with visual disabilities through some pedestrian networks.

Then, in the generation of design alternatives, civil engineering students developed practical assignments to establish layouts of accessible bus stop. The users' needs were perceived by them and were considered in the alternative solutions for accessible bus stops located in the tourist transportation hub. These solutions were in written reports and some oral presentations were presented in an open class were students from two schools of the University of Algarve were involved: Engineering and Tourism. Then the involvement of students stopped here due to the time.

Their proposed design decisions (layouts) were assessed by the main researcher, through technical parameters, to analyse how civil engineering students considered the usability and accessibility concepts, designing for social sustainability, from this experimental education.

3. Results and Discussion

A dynamic of open learning environments was unleashed in which knowledge construction was promoted through problem solving and critical thinking, as well as the presentation of multiple perspectives. These experiences captured the interest of students who acquired a better understanding of the physical barriers that exist in cities and transportation systems. The contact with people with disabilities triggered empathy, as Shinohara et al. advocate [40], and contributed to an understanding of different users' needs and expectations. This understanding and empathy corresponds to the first stage of the design thinking process, which is centred on the human being. Design thinking translated into a team learning process, which is supported by practice-oriented approaches, translating into constructivist learning projects, where motivation for action occurs, openness to new ideas, critical thinking and other cognitive skills. Critical thinking is importance for the future professional of the student, the development of their intellectual capacity and autonomy, and its transversal ability to transfer it to various subjects as well as areas of life [41].

As researchers and students acted, interacted and participated with users in joint activities, they were introduced to new ways of building knowledge, modifying their individual conscience, the way they started to act, changing the contexts in which they participate, such as Engeström advocates [42]. In fact, the development of the collaborative approach helped in understanding some specific aspects for the design of an accessible bus stop. The inquired senior tourists need low floor buses and the associated ramps, space for wheelchair users inside the shelter, as well as, benches with back and armrests, and that tactile surfaces are not important for the oldest tourists. Students navigated together with people with motor disabilities and understood that they need raised platforms at bus stops, barrier-free around the bus stop and soft slopes. They navigated together with people with visual disabilities who have different needs: blind people need tactile surfaces to understand where the bus stop is, where the boarding point is, and where the edge of the raised platform is. Individuals with low vision require colored furniture and surfaces with contrast with the built environment. These

Table 1. Designing for social sustainability by civil engineering students at University of Algarve

Users involved in the collaborative approach	Perceived parameters for accessible bus stop	Students' group 1	Students' group 2	Students' group 3	Students' group 4	Students' group 5
Elderly tourists	Low floor buses and the associated ramps	√	×	√	√	√
	Space for wheelchair users inside the shelter	√	√	√	√	√
	Benches with back and armrests	√	√	√	√	×
	Non-trepidant surfaces	√	×	×	×	×
People with motor disabilities	Raised platform at bus stop	√	√	√	√	√
	Barrier-free around and inside the bus stop	√	√	√	√	√
	Soft slopes	√	√	√	√	√
People with visual disabilities	Guidance tactile surfaces	(a)	√	√	√	√
	Tactile surfaces at the embarkment point	(a)	√	√	√	√
	Tactile surfaces at the edge of the raised platform	√	×	√	×	√
	Contrast color of furniture	√	×	√	√	√
	Contrast color of surfaces	√	√	√	×	√

(a) Tactile flooring was not considered so as not to mislead the blind person and make them rush towards the carriageway, as that type of information is associated with pedestrian crossings.

floors convey the confidence that they can walk independently and safely wherever they are.

All the reports have allusions to the need for the built environment to guarantee equal opportunities for access. Three out of five groups specify the need for a universal design. The other two groups gave emphasis to the needs of blind people, e. g. inclusive design. Both approaches promote the perspectives of multiple participants [43].

The analysis of these layouts shows that students take into consideration all the principles of universal design. Solutions considered the equitable use of outdoor spaces (first principle); the proposed benches with two arms, guarantee flexibility of use (second principle); the free barriers space, around and inside the shelter, increases the access in a simple way guaranteeing intuitive use and access to the panel information (third and fourth principles); surfaces with contrasting colour and tactile marking strips near the kerb of the raised platform alert the pedestrian with impaired vision guaranteeing some tolerance for error (fifth principle); free-barrier pedestrian infrastructure guaranteeing low physical effort (sixth principle); size and space for approach (seventh principle) were considered in the dimensions and soft gradients of the pedestrian infrastructure to allow quality for all.

Most of the layouts present the perceived parameters for an accessible bus stop (Table 1). All the urbanistic criteria were well perceived by the students. Tactile and colored surfaces were considered by the majority of the students.

Group 1 understood that there is no consensus (in the literature) about the use of tactile surfaces on a raised bus stop. In fact, as tactile flooring is, usually, associated with pedestrian crossings, blind people can use them, and this situation can put them in dangerous situations. These students understood, too, that elderly tourists need regular pavements (non-trepidant), and therefore they have different needs from blind people. Modal interfaces must be age friendly and inclusive.

Designers, stakeholders and end users have different values which have to be considered and balanced in the technical decisions taken. There is a necessity for considering the humanistic dimension of resilience taking into account the users and clients of the system [44]. An inclusive and effective community resilience approach needs to be human-centric, individual and communal-sensitive, justice-oriented, and value based consistently [45].

4. Conclusions

Sustainable and inclusive mobility requires social responsibility by civil engineers in planning and designing the built environment and transportation systems. Accessibility for all considers universal and inclusive design to guarantee an essential condition for the full exercise of citizenship rights, translating the right to equal opportunities in access to work, housing, leisure, free time, quality of life, access to tourism activities, among others.

The ACCES4ALL project allowed civil engineering students to gain insights into the design of accessible and inclusive built environment through additional research, study of (inter)national universal design standards, field observation of users and interpretation of questionnaires. They understood the different users' needs, and then they move on to generate design solutions. Proposed design decisions (layouts) were assessed, through technical parameters, to analyse the technical knowledge that civil engineering students have acquired from this experimental education. The proposed layouts show that students absorbed specific criteria they believed were most important, by demonstrating the success of this project in helping students to design for social sustainability.

Students perceived human diversity and the concepts of ''universal design'' and ''inclusive design'' and their implications in the design of the built environment. Universal design is linked with designing one-space-suits-almost-all, and inclusive design focuses on one-space-suits-one, e. g. design a space for everyone (collective perspective) versus design a space for one specific group (particular perspective). Both are important for social sustainability. The built environment must be understandable to and usable by all people. Universal design contributes to social inclusion, but inclusive design is needed, matching the excluded users to the object or space design.

Within this project, students understood the impact of engineering solutions in the lives of people with functional diversity. They had the ability to design a component of the transportation system to meet desired needs within social sustainability. They perceived professional and ethical responsibility to create inclusive solutions considering human diversity. This project-based learning motivated and empowered students to act.

This educational experience shows the role of design engineering in promoting social sustainability. It provided students with the skills to recognize the need of perceived accessibility from different users, and the challenge of implementing universal design principles and inclusive design into products and spaces.

Results suggest that co-design and transdisciplinary co-creation processes are possible models to better prepare civil engineering students for the implementation of sustainable development goals. Collaborative approaches help integrate social sustainability into student design practice.

The perspectives of the built environment's users are fundamental to be known in the design process to achieve the usability of the built environment and transport systems. Pedestrian infrastructures design and modal interfaces demand user centred approaches and so, processes of co-creation with communities.

Objective measures of accessibility (given by standards) and perceived accessibility (given by users) are complementary measures to guarantee the usability of spaces. Perceived accessibility, known through collaborative approaches, could be considered a modern engineering tool necessary for engineering practice. With these current challenges, there is a strong need for a set of skills and competencies by engineers related with ability to work with other professionals (e.g., from the social sciences) and users. This traduces the transdisciplinary approach that ensures collaboration spanning multiple actors, academic and non-academic, to solve societal problems and develop a sustainable world.

In the 21st century, beyond the use of technical knowledge to solve problems, civil engineers need communicational abilities to consider the sustainable development goals and the social and environmental context in which the problem exists, requiring networking, cooperating in teams, and working with communities and people. Civil engineering education must include trans-sectoral and transdisciplinary research and holistic approaches which make clear progress in tackling urban challenges and finding human-centred solutions. This is a time of challenges and opportunities for civil engineering.

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