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Understanding students' perception of sustainability in architecture education: A comparison among universities in three different continents

Paola Boarin [a, *], Antonio Martinez-Molina [b], Ignacio Juan-Ferruses [c]

[a] School of Architecture and Planning, Faculty of Creative Arts and Industries (CAI), The University of Auckland, 26 Symonds Street, 1010, Auckland, New Zealand

[b] Department of Architecture, The University of Texas at San Antonio (UTSA), 501 W. Cesar E. Chavez Blvd, San Antonio, TX, 78207, USA

[c] University School of Architecture, CEU Cardenal Herrera University, San Bartolom,e 55, 46115, Alfara del Patriarca, Valencia, Spain

a b s t r a c t

Educational institutions around the globe have taken definitive steps to curtail the increasing depen- dence on energy in the built environment by promoting the education of sustainability-minded pro- fessionals. Since a large portion of the global energy dependence can be attributed to the building sector, integrating sustainability coursework within the curricula of architecture programmes is a logical development. This study takes a step forward in understanding how different architectural programmes implement sustainability education within their respective curricula. The research team investigated research-focussed and professionally-accredited undergraduate and postgraduate architectural pro- grammes offered by three tertiary education providers in different continents (Oceania, Europe and North America) and assessed their respective impacts on student designs in regard to sustainability considerations. The researchers collected and analysed over 300 student opinions and evaluated their correlation with the educational programmes offered by the institutions through a mapping, an analysis and a comparison activity on the implementation of sustainability-related topics and courses. Results show that nearly all of the participating students generally consider sustainability a key aspect of their education; however, the particularities of student opinions with respect to sustainability outcomes in designs largely vary and seem to depend on the goals and design focus of each programme. This better understanding of the effects produced by the depth and distribution of courses across architecture curricula contributes to the assessment of teaching approaches and learning outcomes from the three universities against the global trends and, therefore, to support ongoing and future curriculum devel- opment activities.

1. Introduction

Over the past ten years, higher education institutions have made definitive efforts to support sustainable development (UNESCO, n.d.). The role of higher education in sustainable development has not, however, always been clear and many institutions did not realise that integrating UN Sustainable Development Goals (SDGs) into their teaching and research agendas could serve as an important catalyst for student engagement (Leal Filho et al., 2019).

This article explores differing approaches to sustainability education, their effects on student awareness and propensity toward sustainable development, focussing narrowly on architecture and the built sector and assessing architecture curricula in three universities around the world. These are: The University of Auckland, New Zealand; The University of Texas at San Antonio, United States of America; and the CEU Cardenal Herrera University, Spain. The three universities use different sustainability education approaches leading to diverse impacts on students' design approaches and practices.

1.1. Historic overview

Sustainable development arguably first drew global attention in

1987, when the World Commission on Environment and Development defined sustainable development as meeting "the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987) and thereby established the guiding standard for sustainable development around the world for decades to come. The role of higher education, however, has not appeared in this discourse until the latter portion of the two-decade-long span. 2012 proved to be an important year in the sustainable development timeline and saw not only a renewed political commitment from the global community at the Rio þ20 Earth Summit and the launch of a process to develop a set of SDGs, but also the creation of the Higher Education Sustainability Initiative (HESI). HESI was created as a partnership between different agencies of the United Nations to provide a unique interface between higher education, science and policy making (Paletta et al., 2019). When the SDGs were revised in 2015 (United Nations, 2015) and the "[t]ransforming our world: the 2030 Agenda for Sustainable Development" created, HESI argued that higher education for sustainable development and the UN SDGs go hand in hand. Specifically, the "Higher Education Sustainability Initiative, 2017 End of Year Report" (Higher Education Sustainability Initiative, 2017) maintained that the ideal moment to share the various innovative practices of implementation of the 2030 Agenda by higher education institutions around the world had come, and provided specific examples of strategic actions member states and higher education institutions could take to incorporate the SDGs (United Nations, n.d.).

Although sustainable development is a broad topic, most of the SDGs address, on a bigger or smaller scale, architecture and the built environment. This is likely so because, in 2009, the United Nations Environment Programme (UNEP) attributed more than 30% of the global gas emissions and 40% of total energy consumption to the building sector (Buildings and climate change, 2009). Higher education has echoed this approach, as evidenced by initiatives introduced by organisations such as UNESCO and its UN Decade of Education for Sustainable Development Programme (UNESCO, 2005) which, from 2005 to 2014, assessed the integration of principles, values and practices of sustainable development in all aspects of education and learning. Moreover, two of the 17 SGDs are 'Quality Education' and 'Sustainable Cities and Communities', both areas where architectural education plays a key role. Thus, although higher education may not have always had a prominent role in sustainable development, international initiatives have caused it to gain an increasingly high profile, especially in the realms of architecture and the built sector.

1.2. Literature overview

Previous research shows the focus on assessing and monitoring the implementation of sustainability teaching in higher education institutions around the world (Cowan et al., 2010; Dumitru, 2017; Hegarty et al., 2011; Svennevig and Hjelseth, n.d.; Tramontin and Trois, 2016; Vincent and Dutton, 2017; Wright, 2003). Due to the impact of sustainability and, particularly, of sustainable development on the built environment, the research community has begun studying the implementation of sustainability education in architecture programmes specifically (Del Rosario Tovar Alc‹azar and Cha‹vez, 2014; Grierson and Hyland, 2013; Porras Alvarez et al., 2016; Wright, 2003). In fact, many research studies have investigated the integration between sustainability education and architectural programmes in various countries. Mavromatidis et al. (2014) pointed out the urgent need for creating a multidisciplinary decision-making process across building and urban design that helps understand the impact of city creation on climate change, applying the Bejan's "constructal law" to describe the natural tendency of flow systems in an interdisciplinary manner. One of the first postgraduate studies in Europe dealing with this issue started in 2014 at Cracow University of Technology in collaboration with the Polish Green Building Council (Celadyn, 2018), where researchers effectively pointed out the importance of incorporating coursework on sustainability in postgraduate architecture programmes. Taking this approach closer to the professional realm, a method was proposed for the institutional development of built environment professions in emerging economies, such as Indonesia, dealing with rapid building and construction markets. This method showed that curriculum development alone is not enough to implement low carbon futures and educationproviders need to work in tandem with several other institutions to drive, complement and support changes for low carbon futures, including linkages with the government, practitioners and the industry (Iyer-Raniga and Dalton, 2017).

Different approaches integrating sustainability in architectural programs have been implemented around the world. Some successful strategies involve initiatives integrating sustainability aspects in already existing courses, creating sustainability-specific courses, and activities to improve students' sustainability awareness. Since design studios are the core unit of study of any architectural programme, extensive published research has proposed new approaches and methods for integrating sustainability within studio teaching (Davis, 2010). For instance, the Naresuan University in Thailand developed activities within the design studio to enforce self-awareness, self-evaluation and self-criticism in order to reform and transform studio teaching toward the integration of sustainable design principles (Hengrasmee and Chansomsak, 2016). Other approaches incorporate building physics and architectural technology in design studio, for instance through the transformation of integral parts of the architectural practice and education from a primarily aesthetic and assembly-oriented trajectory to a more comprehensive understanding of the relationships between design thinking and building performance (Gamble et al., 2015). The way architecture students gain and apply knowledge of sustainable architecture was assessed at the University of Aarhus, Denmark, drawing on second-year architecture student experiences of a one-month introduction course to "Reuse and Materials". The students' baseline knowledge of sustainable architecture was then compared with their subsequent understandings and the opinion they formed (Donovan and Holder, 2016). Mavromatidis (2018) implemented an approach to integrate sustainability into architecture education, combining three educational models of architectural synthesis. This innovative, didactic approach was used in a seminar workshop where it obtained very promising results and refrained from altering student creativity throughout the process.

Given the current global attention on sustainability, the trajectory for the achievement of SDGs and the fulfilment of the Paris Agreement (UN, 2015), there is a great opportunity for tertiary education providers to redefine the core of the programmes offered to architecture students and to 'shape' future architectural graduates. However, despite a general agreement on the importance of integrating sustainability in architectural programmes, transforming the *status quo* by re-shaping the teaching offer and the linkages across teaching units may be perceived as a major obstacle or disruptor in the agenda of an architecture school, in the motivation of educators being responsible for the delivery of lecture courses and design studio and in the overall curriculum (Oliveira et al., 2017). Some other identified impediments to implementing sustainability in architectural curricula also include ambiguous definitions of sustainable architecture, confusion over the meaning of sustainability and lack of experts in this field (Taleghani et al., 2011).

1.3. Originality of the research

All these difficulties need to be overcome to move forward toward an effective sustainability education in architecture schools and further investigations are needed to achieve this ambitious goal. The international research presented in this contribution helps to understand the impacts on students' perception produced by using different academic approaches to sustainability in architectural education. Through the mapping, analysis and comparison of the implementation of sustainability-related topics and courses at the undergraduate and postgraduate levels, both in research oriented and in professionally accredited degrees, the research shows the different effects on students' perception, with a focus on their architectural designs. This better understanding of the effects produced by the breath, depth and distribution of courses across architecture curricula is important to assess teaching approaches and learning outcomes from the three universities against the global trends and, therefore, to support ongoing and future curriculum development activities.

2. Methodology

2.1. Questionnaire

In order to understand what type of sustainability education students currently receive within their architecture programmes, the inter-university research project used an analytical qualitative method with online questionnaires as main tool. The questionnaire included multiple-choice questions (using likert-type scales) and open-ended fields, and was divided into the following sections:

- General Information: personal and related to the programme students are enrolled in;
- Lifestyle: type of accommodation, commuting, sports practised, dietary regime, recycling habits;
- Awareness: knowledge about water and energy consumption of their home/apartment and their appliances;
- Importance of Sustainability in Architectural Education: role of sustainability in architectural education, including design studios, and in their future as professionals of the building industry, and type of sustainability education they received;
- Sustainable Design: key sustainability aspects they usually consider when designing a building;
- Sustainable Thinking: type of compulsory, elective and extra-curricular activities related to sustainability they have completed, awareness of international sustainability rating systems in the built environment, interest in pursuing additional training and/or accreditations as sustainability experts. This section included open-ended questions.

This article is concerned with some sections of the question- naire only, namely: General information; Importance of Sustain- ability in Architectural Education; Sustainable Design; and the open-ended comments in the Sustainable Thinking section.

The on-line survey was offered to undergraduate, postgraduate and doctoral students enrolled in the main professionally accredited and research-focussed architecture degrees in the three universities. An anonymous link to access the online questionnaire prepared on the Qualtrics platform (Qualtrics XM, n.d.) was sent to students of all years and levels and was kept open for 11 months (from June 2018 to April 2019) in order to cover the teaching semesters in both the Northern and Southern hemispheres. The link was distributed to the participants via email, via formal announcements on the courses' teaching management platforms (i.e., Canvas and Blackboard Learn) and via communications during class activities. Reminders were sent periodically by using the same strategies.

Course codes/titles, number of students invited to take part in this research and overall response rates are listed in Table 1.

2.2. Notes on the scope and methodology of the research

- This paper considers applications of sustainability concepts at the architectural (building) level only and not at a larger community or city scale.
- This paper considers the conservation of energy through both passive and active systems, as this field was identified as a common ground (and therefore comparable) across the architecture curricula in the three universities.
- The courses where the questionnaire was offered were not chosen for their topic, but because they involve a whole year cohort of students, thus ensuring the broadest distribution possible. In addition, those courses' co-ordinators allowed the researchers to publish the announcement and the link to the questionnaire on their digital teaching platforms and to give a brief presentation in person during class time, thus ensuring as much participation as possible.
- Because the researcher from the University of Auckland (UoA) involved in this study taught courses with more than one group of students to which the questionnaire was offered, the UoA Human Ethics Committee required student responses not to be associated with a particular course, but only with one of the following general categories: undergraduate, postgraduate or PhD. This avoided student concerns related to their identification and allowed for a greater volume of responses and a more honest feedback.

3. Architecture curricula analysis[1]

The following sections discuss how sustainability is integrated in the main architecture degrees that are currently offered by the three universities involved in this research project to date. Appendix A 1, Appendix A 2 and Appendix A 3 show the progression of knowledge through the degrees for each university, from undergraduate to doctoral studies, highlighting how much the courses implement sustainability throughout the curricula. Appendix A 4 shows all the degrees from the three universities as a combined diagram, allowing for a comparison among all architecture degrees analysed, in terms of length of programmes and distribution of courses. These degrees are not the only ones offered by the involved universities but are the most important ones in architecture education.

Diagrams presented in Appendices A 1 e A 4 classify courses in the curricula according to their level of attention to sustainability, as defined in the scope of this study, defining four categories:

- courses with a primary sustainability focus, i.e. courses specifically designed to address sustainability challenges (such as designing for climate-sensitive architecture, for human comfort, for indoor environmental quality, etc.) and where learning outcomes and assessment tasks are tailored to develop the

[1] Note on course credits across the universities considered: 1) at the University of Auckland 1 credit is equal to 10 hours of workload (class contact time and students' directed work); 2) at the University of Texas at San Antonio 1 semester-credit-hour is equal to 45 hours of workload (class contact time and students' directed work); 3) at the CEU Cardenal Herrera University 1 credit is equal to 10 hours of workload (class contact time and students' directed work).

Table 1
Courses and number of students invited to complete the survey and related response rates. Note: only cumulative number of respondents for UG and PG were collected (see section 2.1 for clarifications) and used to calculate the response rate for each university and the response rate for the research as a whole.

	Undergraduate courses				Postgraduate courses			
	Course code	*No. invited*	No. responded	Response rate %	Course code	*No. invited*	No. responded	Response rate %
University of Auckland (UoA)								
	ARCHDES 102 e Design 1	116			ARCHDES 700 e Advanced Design 1	117		
	ARCHTECH 207 e Design Technology 1	129			ARCHDES 796A e Thesis	103		
	ARCHTECH 307 e Environmental Design 2	122			ARCHDES 799B e Thesis	26		
					ARCHGEN 793 e Thesis	1		
					PhD in Architecture, Urban Design and Planning	63		
Overall UoA participants		*367*	*41*	*11%*		*310*	*33*	*11%*
University of Texas at San Antonio (UTSA)								
	ARC 2233 e Principles of Environmental Systems	40			ARC 5733 e Advanced Building Technology and Sustainability	16		
	ARC 4156 e Building Design Studio I	15			ARC 6136 e Advanced Topics Studio	18		
	ARC 4183 e Environmental Systems	72			ARC 6146 e Advanced Technical Studio	15		
Overall UTSA participants		*127*	*101*	*80%*		*49*	*42*	*86%*
CEU Cardenal Herrera University (UCHCEU)								
	Introduction to Architecture	25			PhD in Design, History and Technology of Architecture and Urbanism	4		
	Architectural Projects I	20						
	Architectural Projects III	20						
	Architectural Projects V	20						
	Architectural Projects VII	25						
Overall UCHCEU participants		*110*	*66*	*60%*		*4*	*0*	*0%*
TOTAL RESEARCH PARTICIPANTS		604	208	34%		363	75	21%

ability of incorporating environmental sustainability though design applications;
- courses with a tangential sustainability focus, i.e. courses where sustainability aspects are not at the forefront, but substantially inform teaching aims and learning outcomes. An example is ARCHTECH 207 e Design Technology 1 at the UoA, a course primarily concerned with construction technologies, but that at the same time incorporates substantial considerations about the selection of materials for structures (such as their origin, treatments and emissions), their quality and energy efficiency outcomes (for instance though the appropriate executions of building detailing);
- courses with a possible sustainability focus or minor attention to sustainability, i.e. courses where the topic may be different at every teaching offer or according to the teacher (usually sessional or in supervisory mode), or where sustainability is not directly addressed, but represents a background knowledge. Examples of these courses are design studios and thesis work;
- courses with no sustainability focus, i.e. all the remaining courses in a curriculum, predominantly falling under other disciplines (such as, history, theory, media and representation).

Courses were then associated with one of the categories above on the basis of a combined analysis of:

- course prescriptions from official University Calendars, which are approved at School, Faculty (where relevant) and University level;
- teaching aims and learning outcomes of each course from the official Course Outlines, which are approved by Discipline Leaders and Head of Schools/Department;
- direct conversations with Discipline Leaders and course Directors and/or Co-ordinators.

3.1. School of Architecture and Planning at the University of Auckland, New Zealand

At the University of Auckland School of Architecture and Planning, a clear "theorized" teaching approach is used (Lebahar, 2001; Mavromatidis, 2018), and sustainability is directly incorporated into all levels of the teaching offer through a combination of dedicated units of study and modules within larger courses; it is also an overarching topic indirectly addressed by design studios at both undergraduate and postgraduate levels.

At the undergraduate level, the School offers a 360-credit, three-year Bachelor of Architectural Studies (BAS), which introduces the fundamental aspects of architecture. The BAS categorises its courses into discipline streams and the topic of sustainability falls within the Architecture Technology stream, which comprises five 15-credit courses offered at all stages of this programme. Out of the five courses, one includes a module, which introduces the topics of sustainability and resilience in the built environment (year one), two are specifically dedicated to environmental sustainability, en- ergy performance and human comfort (year two and year three), and two are more focussed on architecture technology while also

incorporating principles of material and energy efficiency and the reuse of resources (year two and year three). Out of the six, 30- credit design studios offered in each semester of each year level, only the first offered in year one includes a specific extensive module on sustainability, while, in all the others, sustainability is addressed as a background topic and depends on the tutor teaching the design studio. Only Design 6, the last design studio of the BAS, asks the students to work on the detailing of their project as a requirement for accreditation and, therefore, might include con- siderations to avoid thermal bridges.

At the postgraduate level, the School offers a 240-credit, two-year professionally-accredited Master of Architecture (Professional) (MArch(Prof)) degree, comprising of a first year focussed on coursework and allowing students to develop a supervised thesis project in the second year. Here, sustainability is delivered through three 15-credits elective seminars offered in the first year[2], and two 30-credit advanced design studios, which address sustainability as an overarching or background topic. In the second year of the MArch(Prof), students choose the focus of their thesis projects from a wide range of topics, including real or speculative investigations on advanced sustainable designs. The MArch(Prof) degree can also be coupled with other disciplines (e.g., the Master of Architecture (Professional) and Heritage Conservation (MArch(Prof)HerCons) or the Master of Architecture (Professional) and Urban Planning (Professional) (MArch(Prof)UrbPlan(Prof)), allowing for even greater exposure to modules addressing sustainability.

The School also offers a 120-credit, one-year Master of Architecture in Sustainable Design degree, which is a research-focussed qualification. This degree can be achieved by means of either a full 120-credit thesis or a 30-credit taught component (i.e., including two elective seminars in sustainability chosen from the three offered at the MArch(Prof)) combined with a 90-credit thesis. After a Master, students willing to continue in a research path or career can enrol in the Doctor of Philosophy (PhD) qualification, which comprises the disciplines of Architecture, Urban Design and Urban Planning. Sustainability-related enquiries are largely investigated by students whose research falls under the streams titled “Resil- ience and Sustainability” and “Urban Design, Spatial Planning and Place Making”.

3.2. Department of Architecture at the University of Texas at San Antonio (UTSA), USA

The University of Texas at San Antonio (UTSA) Department of Architecture offers sustainability-related courses mainly through specific modules within its Bachelor of Science (BS) in Architecture and Master of Architecture curricula. Unlike UoA and UCHCEU (addressed below) sustainability is not integrated into the overarching teaching offer at UTSA, and a “theorized” pedagogic method focused on research is applied (Lebahar, 2001; Mavromatidis, 2018).

The BS in Architecture is a 121-credit, pre-professional programme at the undergraduate level. It includes a total of four courses where sustainability aspects are integrated as modules into the programmes and four courses exclusively and specifically focused on sustainability in their entirety (i.e., two, 3-credit lecture courses and two 6-credit design studios). These courses dig into environmental, thermal, energy, lighting and acoustical performance of buildings. Additionally, some other covered topics are passive and active environmental system strategies, daylighting, architectural lighting systems and acoustic systems, building design performance, human factors related to building indoor environmental quality, mechanical heating, ventilation and air conditioning (HVAC) systems and photovoltaic systems. At the postgraduate level, the 33-credit Master of Science in Architecture degree offers a set of ten, 3-credit, elective courses in sustainability in addition to three, 6-credit, advanced design studios and 6-credit-hours Master’s Project Studio. Students registered in these studio courses work on and develop sustainable architectural projects that deal with thermal, visual, acoustical and environmental processes. While UTSA does not currently offer a Doctor of Philosophy (PhD) in Architecture, from 2020 the College of Architecture, Construction and Planning will offer a new PhD programme in collaboration with the College of Engineering. One of the two tracks that will be offered to the students will focus entirely on sustainable architecture and will be titled the “Building Performance Track”.

In addition to the teaching offer described above, the Department of Architecture extends skill-focused opportunities. For example, a 15-credit Graduate Certificate in High Performance Design and Sustainability is available for students who have completed selected electives and wish to receive a tangible confirmation of their skills and comprehension of sustainable architecture.

3.3. School of architecture at CEU Cardenal Herrera University in Valencia, Spain

The School of Architecture of the CEU Cardenal Herrera University (UCHCEU), focuses on teaching the tools, skills and a exclusively professional point of view, to the students of architecture. This is a “professionalist” pedagogic method (Lebahar, 2001; Mavromatidis, 2018), where sustainability is understood to be a cornerstone in the development of an architect’s training and not a specific, isolated concept to be developed through individual courses. This is why the BA and BFA degrees (as described below) do not strictly include isolated subjects directly related to this topic; instead, sustainability is incorporated throughout the degree in both creative and applied courses.

Currently, UCHCEU has two active degrees as the university is transitioning from the Bachelor in Architecture (BA), a 330-credits professionally accredited degree currently offered to students enrolled in the 4th, 5th and 6th years only, to the Bachelor in Fundamentals of Architecture (BFA), a new 300-credits, five-year non-professionally accredited degree currently offered to 1st, 2nd and 3rd year students. From the academic year 2021e2022, the BFA will be completed by a one-year Master’s Degree in Architecture (MDA), which will give the student an opportunity to register and practice as professional architects. This change, motivated by the Royal Decree 861/2010 of July 2 and the Resolution of July 28, 2010, of the General Secretariat of Universities in Spain (Ministerio de Educacio›n, 2010), was seen as an opportunity to rethink the teaching offer in architecture through the pursuit of a more integrated methodology.

At the undergraduate level, in the BFA, sustainability accompanies the students in each of the courses through modules of knowledge linked to the subjects of Urbanism and Building Services, but mainly it is linked to the Architectural Project (AP), which is the most important part of the degree, with 67.5 credits allocated out of the total 300 credits. Two of these APs are distributed in each year, from the 2nd to the 5th. In the development of these subjects, sustainability is integrated as strategic knowledge and directly

[2] Students have to choose one elective seminar per semester from a pool of 18 courses on several topic areas. Seminars offer changes almost every year. For those students who choose to pursue a thesis in a sustainability-related topic, it is not mandatory to choose a sustainability-focussed elective seminar (although it is highly recommended), as the School encourages students to gain a wide breadth of knowledge.

applied to the designs developed by students. A content module linked to the two subjects of each academic year is provided as follows:

- in the second year, the module of "Introduction to the triple bottom line: economic, ecological and social" is taught and applied to the subjects of AP1 and AP2;
- in the third year, the module of "Environment and place: implementation, climate, environment and landscape" is taught and applied to the subjects of AP3 and AP4;
- in the fourth year, the "Ecology and energy" module is taught and applied to the subjects of AP5 and AP6;
- in the fifth year, the module on "Ecological materials and bio-construction: circular economy" is taught and applied to the subjects of AP7 and AP8.

In parallel to the AP subjects, each course has a subject titled "Technical Development of Projects" which analyses and complements the design studios, focussing on the technical, sustainable and material decisions used.

Starting in 2021, after completing the BFA, students will be able to complete their studies with a 60-point MDA, where Architectural Projects (12 credits) and Construction of the Project (9 credits) integrate sustainability as an active and fundamental parameter in each of the phases of the development of the project.

Finally, students can round out their education at UCHCEU by enrolling in a Doctorate Programme (PhD) in Composition, History and Technique in Architecture and Urbanism, which that to develop new knowledge by focussing on research in areas related to the conceptual, sustainable and technological dimensions of both disciplines.

3.4. Summary of architectural curricula in the three universities

The main highlights arising from the architectural curricula analysis are:

- UoA and UTSA offer professionally accredited degrees in Architecture which are not extensively focussed on sustainability, but also offer research degrees dedicated to sustainable architecture which can be the pathway towards doctoral studies (this will happen from 2020 for UTSA);
- UoA and UTSA use a vertical model of integration, where sustainability education is delivered through a dedicated disciplinary stream and, in general, courses achieve a deep knowledge;
- UCHCEU uses a horizontal model of integration, where sustainability education is extensively embedded across the courses within the curricula, but these courses are not exclusively dedicated to sustainability;
- at the UoA and UTSA, sustainability considerations are less integrated with design studios and depend on the knowledge and willingness of design teachers, hence offering less opportunities for the implementation of sustainability applied to design projects;
- at the UCHCEU, all design studios across the curricula incorporate sustainability quite extensively, in an attempt to take an applied and integrated approach to the subject;
- both UoA and UTSA follow the "theorized" pedagogic method, while UCHCEU follows the "professionalist" method defined by Mavromatidis (2018).

4. Results of the research

The results analysed in the following sections of this article refer to the following questionnaire sections:

- Importance of Sustainability in Architectural Education;
- Sustainable Design;
- Sustainable Thinking (open-ended comments).

4.1. Importance of sustainability in building design and architectural education

A large number of students across the three universities considered sustainability as a critical aspect of design, but there are some relevant differences (Fig. 1). It is in fact interesting to highlight

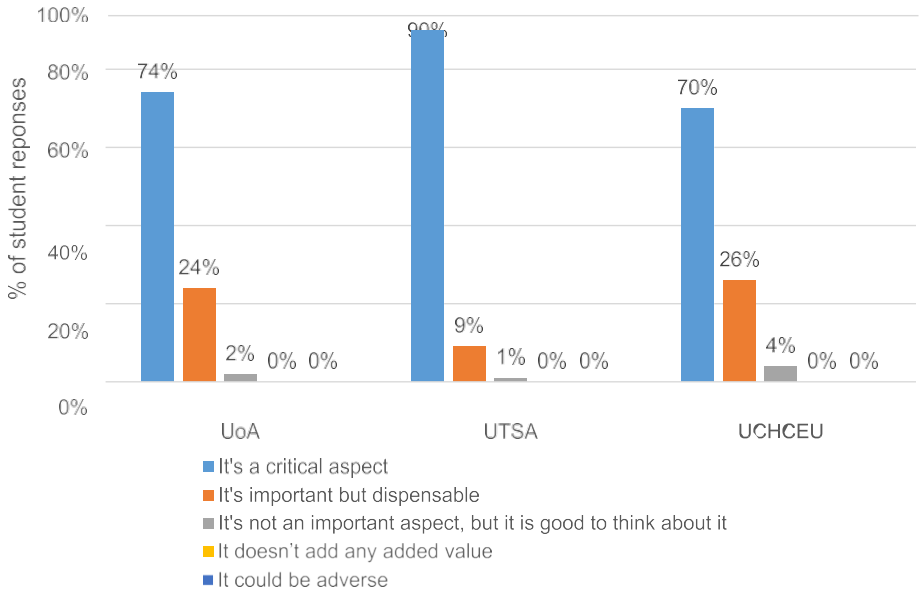

Fig. 1. Comparison among students' perceptions of the importance of sustainability in building design.

that the highest number of students (30%) considering sustainability as a dispensable or as a non-important aspect were from the university where sustainability is taught the most and through a fully integrated model, i.e., UCHCEU. The UoA follows this picture with 26%, but this figure is much more consistent with degrees structures and pedagogical models which do not always support an integrated approach to sustainability education. UTSA had the highest number of responses in favour of sustainability being a critical aspect of building design (90%), which is remarkable given the great majority of respondents were from the undergraduate degree where the subject finds little space in both lecture-based courses and design studios.

Architectural sustainability is affected by building design and also by occupants' interaction with the construction. Students were asked about the impact of these two aspects on building sustainability performance. Around 80% of students from the three universities responded that building design has a big impact on building sustainability, around 20% thought the impact is moderate, while only 2% of UTSA and 5% of UCHCEU students thought that design has a minor impact on sustain- ability (Fig. 2).

It is interesting to note that, when asked about the relationship between sustainability and occupants' behaviour (Fig. 3), students overall rated this aspect similarly to the previously-assessed impact of design (UoA 83%, UTSA 79%, UCHCEU 82%), although there is a different distribution of grades in the higher band of the scale, in particular for the UoA and UCHCEU.

If contextualised in the wider architectural education realm (Fig. 4), the three programmes obtained similar results, with almost 100% of respondents considering sustainability important or very important in their education. Only a very small number of UCHCEU (3%) and UTSA (2%) students considered sustainability a minor aspect in their education. Since basically every student across the three universities considered sustainability critical in their architectural education, this is an important result for this research.

4.2. *Applied sustainability knowledge*

When asked about what fundamental sustainability concepts students usually considered when designing a building, responses showed very interesting variations among the three universities (Fig. 5). In order to obtain a large and diverse sample size, the questionnaire was submitted to entire student groups, rather than particular students. Therefore, any variation in student performance is negligible and disbursed into the results. Fig. 5 also offers the opportunity to understand the basic aspects that the students did not know or aspects that, although included in their teaching curriculum, were not well-received by the students, regardless how advanced their architectural education is. Overall:

- topics related to the building location and natural ventilation were those considered the most;
- topics related to water metering and waste management were those considered the least;
- topics related to Volatile Organic Compounds (VOCs) and, again, installation of water meters were those most unknown and the overlap of the latter with the previous category suggests that perhaps a number of students ranked as not important a subject they really did not know well.

It is also worth highlighting that passive design strategies, which are a group of measures with the strongest relationship with the design of a building and entirely the architect's responsibility, were not among the student's top three responses (5th choice). Additionally, the fact that water-related aspects like rainwater harvesting, indoor water efficiency and water meters, were among the least considered while designing a building is a critical problem to overcome. These are very important results of this research, with possible impacts on the future delivery of sustainability courses across the three universities.

5. Discussion

Appendix A 4 provides an opportunity of assessing and comparing the current main architectural education offer in the three universities and to comment on how sustainability is incorporated to allow a laddered knowledge.

5.1. *The integration of sustainability in architectural curricula*

The main difference between the three academic offers is the

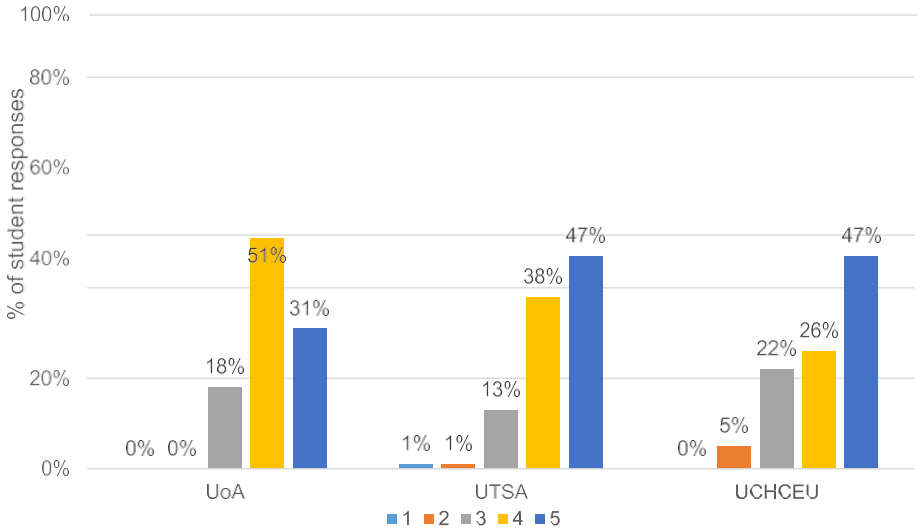

Fig. 2. Comparison among students' opinions about how much sustainability of a building depends on design (1 means not at all, 5 means a lot).

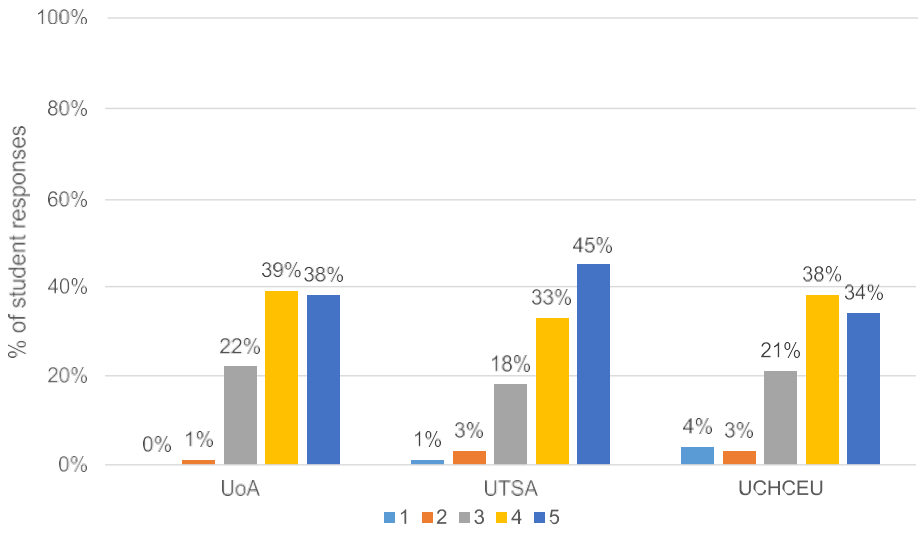

Fig. 3. Comparison among students' opinion about how much sustainability of a building depends on its use and users' behaviour (1 means not at all, 5 means a lot).

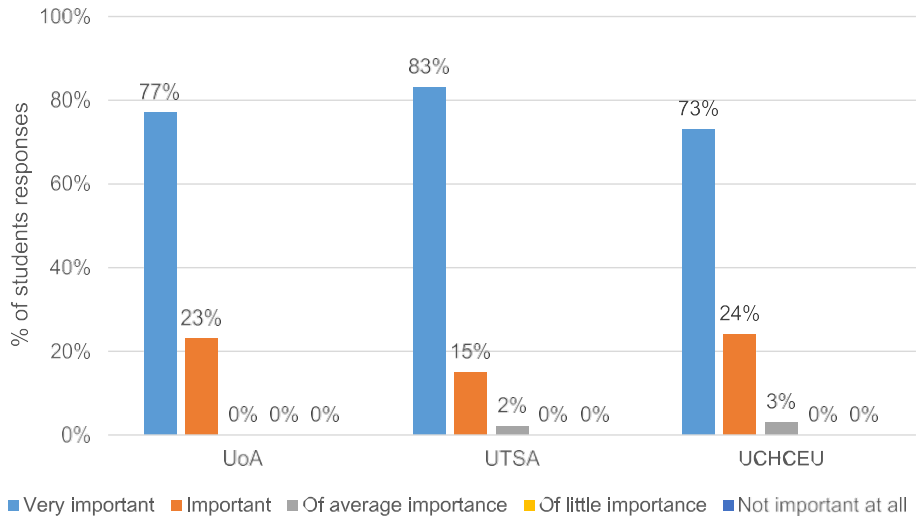

Fig. 4. Comparison among students' perceptions of the importance of sustainability in architectural education.

way sustainability is integrated in the curricula. At the UoA and UTSA, sustainability is mainly confined to discipline-specific courses that have little or no connections with courses beyond the stream, and to optional elective courses that can be chosen from a larger pool of courses available to the students. In alignment with Davis' observations (2010), the integration of sustainability with design studios is limited to the topic being considered as background information to the design realm and explored only to the extent of statutory requirements, which can lead to very limited sustainability outcomes, especially in the case of New Zealand. In addition to this, as design courses are not offered by permanent staff members only, but by practitioners as well, the level at which sustainability is integrated within the design process is not consistent across the year levels and varies from courses where this is not considered at all to others where it is the main driver for design and a tool for creative outcomes. In the UoA example, in fact, in order to keep the students-to-tutor ratio within the acceptable ranges necessary to offer good supervision and guidance (e.g., around 18:1), it is necessary for the School of Architecture and Planning to contract external professional tutors (usually 5 out of the total 7 tutors involved in the delivery of a design studio for each year's cohort). These external tutors are an absolute added value to the School in terms of the professional experience that they can transfer to the students; however, they may not share the same understanding and knowledge about sustainability or give sustainability the same importance and role within the architectural process. In addition, in order to offer a broad design agenda to the students, each tutor in the same studio course has the opportunity of delivering a slightly different topic, although they all must fit under the same semester topic. If this approach supports diversity and inclusion and is well-aligned with a highly international student cohort, not all students will be exposed to the same sustainability concepts or at the same level. This issue is not present at the UTSA, where there is only one design studio group, with a balance between permanent staff and contracted professionals, all following an overarching programme but with the possibility of customising it every year. Nor is it present in UCHCEU, where there is only one design studio group, typically taught by a permanent

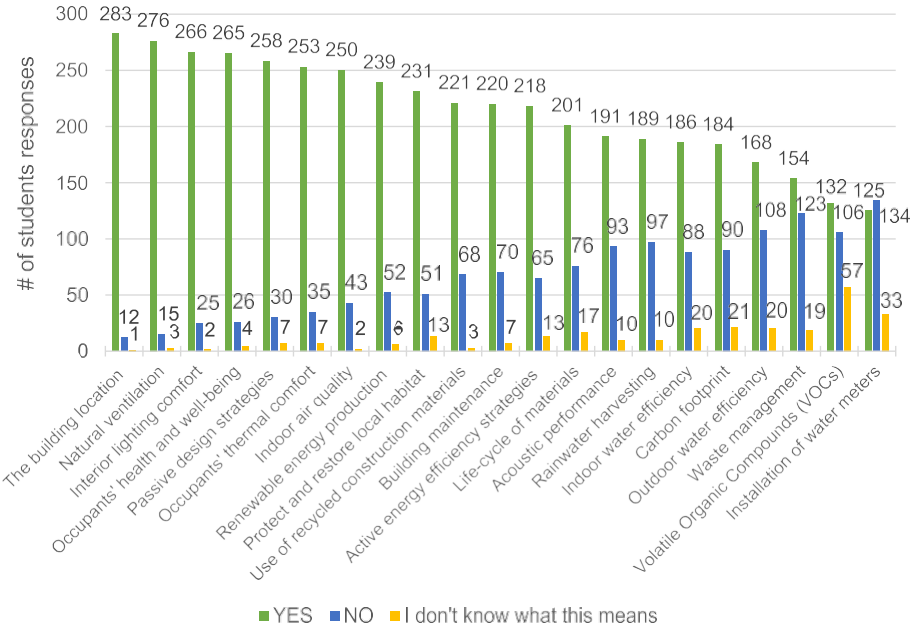

Fig. 5. Number of students' responses to what sustainability aspects are considered when designing a building (combined results from the three universities).

staff member or by a contracted professional following a pre-approved programme. On the other side, the European model used at UCHCEU has a lower number of lecture courses dedicated to sustainability, but a higher number of design studios where sustainability concepts are brought together for an integrated outcome.

Education is a strategic factor in the pathway toward the achievement of sustainable development worldwide, as acknowledged by the United Nations through the Sustainable Development Goals (United Nations, 2015), and the integration of sustainability in architectural curricula has the potential of addressing the issue of reducing the CO_2 produced by the building sector, which accounts for almost 40% of global emissions (United Nations Environment Programme (UNEP), 2012). However, Ramos et al. (2015) have identified the existence of many challenges in the integration of environmental education and education for sustainable development in higher education institutions, often leading to compartmentalisation of knowledge and mono-disciplinary barriers to change, as confirmed by this research.

5.2. *Undergraduate vs. postgraduate courses and students*

While sustainability is mostly delivered through lecture-based courses at the undergraduate level, it is mainly delivered through elective courses at the postgraduate level in the professionally accredited degrees, thus becoming a matter of the students' individual choice, as confirmed by Iulo et al. (2013) as well. This is due to the higher level of customisation of these higher degrees to support the different disciplines of the architecture profession in which students can specialise. If students choose sustainability-oriented elective courses, they will more likely explore the topic in their Master's thesis. The extent of sustainability contents is greater in research-focussed degrees (not professionally accredited), where students receive a combination of lecture-based and studio-based teaching addressing the topic in its breadth and depth, as in the example of the Master of Architecture (Sustainable Design) at the UoA and the Master of Science in Architecture (Sustainable Architecture) at UTSA. Students choosing these research degrees usually intend to progress their studies further toward a PhD or want to become specialists in the field after receiving a professionally accredited qualification. Alternatively, as pointed out by Iulo et al. (2013), these students would also become valuable teaching assistants and eventually teachers in undergraduate courses, as it happens at UoA and UTSA. Sometimes, these courses are also used as a transitioning qualification toward the enrolment in other programmes, especially in the case of international students. To this regard, it is worth mentioning that it is possible for students coming from other Universities to enrol in postgraduate courses at the UoA and UTSA, thus highlighting possible differences in the background knowledge of incoming students. This is not an issue in the case of UoA and UTSA as the student retention rate between the undergraduate and postgraduate degrees in Architecture analysed in this paper is around 70% (74% in 2018 at UoA and 73% in 2018 at UTSA). This datum is not applicable to UCHCEU because they currently don't have a Master's programme.

5.3. *Sustainability in professionally accredited degrees*

Degrees in New Zealand, the USA and Spain have different requirements in regard to professional accreditation, but they definitely mirror the characteristics of the architecture profession in the three countries. In New Zealand and the USA, architects are mainly responsible for the design level of a development and, generally, have little or no involvement in decisions related to structures, building services and, more broadly, around the selection of specifications related to energy efficiency. On the contrary, in Spain, architects are responsible for both the architectural design and the definition of all technical specifications, with the responsibilities extending to structures, building services and energy efficiency of buildings. Considering this scenario, it is critical for architects in New Zealand and USA to know how they can impact on the overall building sustainability through their design and also to understand how a concerted process involving other professionals in the construction process can lead to more sustainable outcomes. Differently, for architects in Spain, a higher level of

specialisation becomes even more important in order to maintain a competitive profile on the market, but understanding the limitations in their scope of work and responsibility is essential and can lead to a more efficient collaboration with other professionals.

An interdisciplinary and integrated approach is a strategic aspect of architectural education and a key to professional success. Nonetheless, a shared framework for the accreditation of architecture curricula and a set of common qualification criteria do not exist, showing a gap in the field and making the idiosyncrasies of an environment-related architectural education more evident. This research confirms Altomonte's view (2012) who discusses how criteria established by professional bodies "are often inhomogeneous and characterised by loose requirements, especially in prescribing an effective balance between creative and technical abilities". This lack of a shared framework and of quantifiable criteria often represents a challenge when dealing with the mutual recognition of professional qualifications across universities worldwide, but also a potential issue in regard to the movement of professionals from country to country.

5.4. *Integration of sustainability in designs*

In regard to the importance of sustainability in design, it is relevant to mention that UTSA has only two courses dedicated to sustainability at the undergraduate level, but 90% of the student body regarded sustainability to be a critical aspect in building design. This highlights the great potential to integrate this topic inside design studios, which is currently very limited at UTSA. On the other hand, at UCHCEU, where sustainability is incorporated in all design studios and inside many other courses at all levels of the bachelor's degree, only 70% of students felt this to be a critical aspect. The UoA result of 74% is overall less surprising, as only two courses and one module in a third course are offered to students, while another one is offered as elective.

In regard to the field of applied sustainability knowledge, i.e. concepts that are typically used by the students in their designs, the survey allows for some reflections on the topics that are more- and less well-received. At the UoA, passive design strategies rank just 7th in the scale of the most used aspects, in favour of the choice of the location, natural ventilation, lighting and thermal comfort, indoor environmental quality and indoor air quality. This is perhaps a result of the siloed-type of knowledge that is being addressed in the current implementation of the new BAS review. On the other hand, it is worrisome to see that Volatile Organic Compounds (VOCs) and outdoor water efficiency are among the topics that students did not recognise as being part of their edu- cation, given that they are present in two lectures dedicated to these subjects. UTSA's results mirror the overall outcomes for this question, focussing mainly on passive strategies and occupants' satisfaction. Other sustainability ideas such as energy generation, water management and materials were not commonly consid- ered. It is worth mentioning that UTSA students considered acoustics less important than in the other two institutions, although carbon footprint is far up in the list. The sustainable concepts that UTSA students knew the least were in parallel with those of the UoA and UCHCEU, i.e., waste management and VOCs and water meters. Results also show that many UTSA students purposely chose not to include technologies for water efficiency, acoustic performance and waste management. UCHCEU students placed more importance on the strategies most related to the decisions of the project such as the selection of the building site and the natural ventilation and comfort of the users, giving less priority to the most technical aspects such as avoiding/reducing VOCs, rainwater harvesting or carbon footprint. It is possible that the integrated approach focussed on architectural projects gives more attention to design conditions and passive decisions with less priority given to those technologies that could improve the sustainability of such projects even more, and sometimes without even knowing some of the applicable strategies.

As discussed by Mavromatidis (2018), technological knowledge and building physics are not a constraint to the development of the architectural idea, but "a fundamental element that contributes to the aesthetic development of formal solutions". To this regard, this research has highlighted the need for the three universities to build stronger connections between the theoretical and design dimensions of sustainability. Sustainability can be a driver for creativity in design as long as its scientific dimension is integrated as early as possible in the architectural education, thus contributing to the morphogenesis of the project.

5.5. *Highlights from the open-ended comments*

At the end of the questionnaire, respondents were given the opportunity to add additional open comments regarding their sustainability education, some of which are worth highlighting.

There was a common thought that sustainability should be more integrated into design studios and not be a topic for courses or seminars only. The perception was that, if the topic remains something for theory only, it will never become mainstream and have the necessary impact on a wide scale, while, if implemented through studios, it will develop binding connections with the design action, becoming an integrated process. As these comments mainly arose from students at the UoA and UTSA, where less integration between lecture courses and design studios is present compared to UCHCEU and the European model in general, they highlight a potentially dangerous outcome of this pedagogical model. For instance, at the UoA, the current BAS review is leading the courses in the Architecture Technology and Sustainability stream becoming much more integrated; however, connections with design studios have been difficult for a long time now, although something has positively changed in the 2019 offer, with ARCHDES 102 e Design 1 having a strong sustainability component. One of the reasons for these difficult connections is the high number of non-academic professional staff involved in the delivery of design studios, as discussed in section 5.1.

A comment from a student at UTSA highlighted a common propensity among people (also beyond the student body) who are keen to discuss sustainability matters, but, when it comes to their own personal commitment to sustainability in their everyday life, they are "not willing to do a simple thing like turn off the computer or lights off after leaving the room, or walk 5 min instead of driving". This comment reveals that a 'not-in-my-back-yard' approach is still very present among students and this represents a very worrisome signal that environmental concerns are not regarded as a concrete matter on which we can have an impact through our daily activities and, perhaps, it also demonstrates that climate scepticism is still widely diffused. This seems to be confirmed by a further comment by a UoA student, who highlighted that, although "[s]ustainability is one of the 'frontline' issues for architects today, it's a small piece in a bigger puzzle". This issue was highlighted in Iyer-Raniga and Dalton (2017) as well, who pointed out that "curriculum development alone is insufficient to bring about broad scale and lasting changes to low carbon futures".

It is worth mentioning that the implementation of sustainability goals in the built environment became compulsory in New Zealand only in recent times and with lower performance requirements compared to other countries. Architecture schools in the USA have sustainability well-integrated within their curricula and are leading most of the world's sustainability research.

However, this robust structure does not translate into a more sustainable and saving society; in fact, the USA is considered as the most wasteful and energy consuming country in the world, spending 21% of the world's energy (The World Bank, n.d.). In Spain, schools of architecture have never previously focussed on sustainability. That is why architecture, urbanism and the Spanish construction sector in general have not evolved sufficiently in this direction compared to other European countries. In fact, as pointed out by Lo‚pez De Asiain et al. (2011), Spain has only recently started to integrate sustainability contents in architec- ture curricula and there is still much to improve in all areas of knowledge regarding this topic.

6. Conclusion

This contribution has analysed how sustainability education is delivered through architectural degrees offered in very different geographical and political contexts, i.e., at the University of Auckland, New Zealand, at the University of Texas at San Antonio, United States of America, and at the CEU Cardenal Herrera University, Spain. The results show that, regardless the level of implementation of sustainability teaching, which differs across the three universities, almost every student considered sustainability as a critical aspect in their architectural education. This is to be taken as an important driver for further theoretical and applied sustainability knowledge in all three universities, while also considering the current opportunity given by the ongoing structural reviews of some of the degrees. Additionally, a comparison between curricula in the three universities shows that disciplinary silos are still pre- sent outside Europe and that sustainability subjects tend to be mostly delivered through lecture-based courses with very little integration with design studios, especially at the undergraduate level. It is assumed that sustainability education should be deliv- ered within a more fully-integrated pedagogical framework, where sustainability itself becomes a driver for creative practice in the pursuit of a greater interdisciplinary, multidisciplinary and trans- disciplinary approach. However, this research results do not show that this is a more successful approach. These findings are very relevant and helpful to future sustainability integration in archi- tectural curricula.

Some limitations of this study can be summarised in the following points:

- the lack of data from individual courses to which the questionnaire was offered, for reasons related to Human Ethics requirements, as explained in section 2;
- the lower response rate from UoA students compared to the other two universities, which, however, seems in line with the current UoA trend on low response rates for any student survey, including the Summative Evaluation Tool (SET), which is the official course and teacher quality evaluation.

This paper considered the architectural view point related to the conservation of energy through both passive and active systems at the building scale, but future developments could expand the breadth and scope of the research toward the neighbourhood and city scales;

It is worth noting that all three universities are currently going through structural changes involving entire curricula or just architecture technology courses, and are at different stages of implementation. This study was therefore very useful to assess what is currently being done and to highlight possible future improvement that will be incorporated in the ongoing review. At the UoA, the opportunity of the review of the whole BAS was taken to strengthen the connections with design studios by developing appropriate design-based assessment tasks and extending the range of topics taught in order to cover a wider range of building design and performance subjects, both qualitative and quantitative. At UTSA, the future offer of a doctoral degree including a stream on building performance will allow students coming from the Master of Architecture Professional, but predominantly from the Master of Science in Architecture (Sustainable Architecture), to complete a research path focussed on sustainability-related topics and perhaps start a career in tertiary education or as a R&D professional. It is important to note that this opportunity arises from the collaboration with the College of Engineering. At UCHCEU, the ongoing implementation of the new Bachelor in Foundations of Architecture and the subsequent new offer of a Master Degree in Architecture will allow students to pursue professional registration as architects. Given these major transformations, these three universities will therefore need to demonstrate resilience, flexibility and adaptability to change, and a strong commitment to monitoring the results and impacts of these changes on a disciplinary and pedagogical level.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors are grateful to the students of the School of Architecture and Planning at the University of Auckland, the Department of Architecture at the University of Texas at San Antonio, and the School Technical Teachings at the CEU Cardenal Herrera University for their participation in the questionnaire. The authors also acknowledge the contribution and support of staff members and administrative staff who helped in the distribution of the questionnaire to the students.

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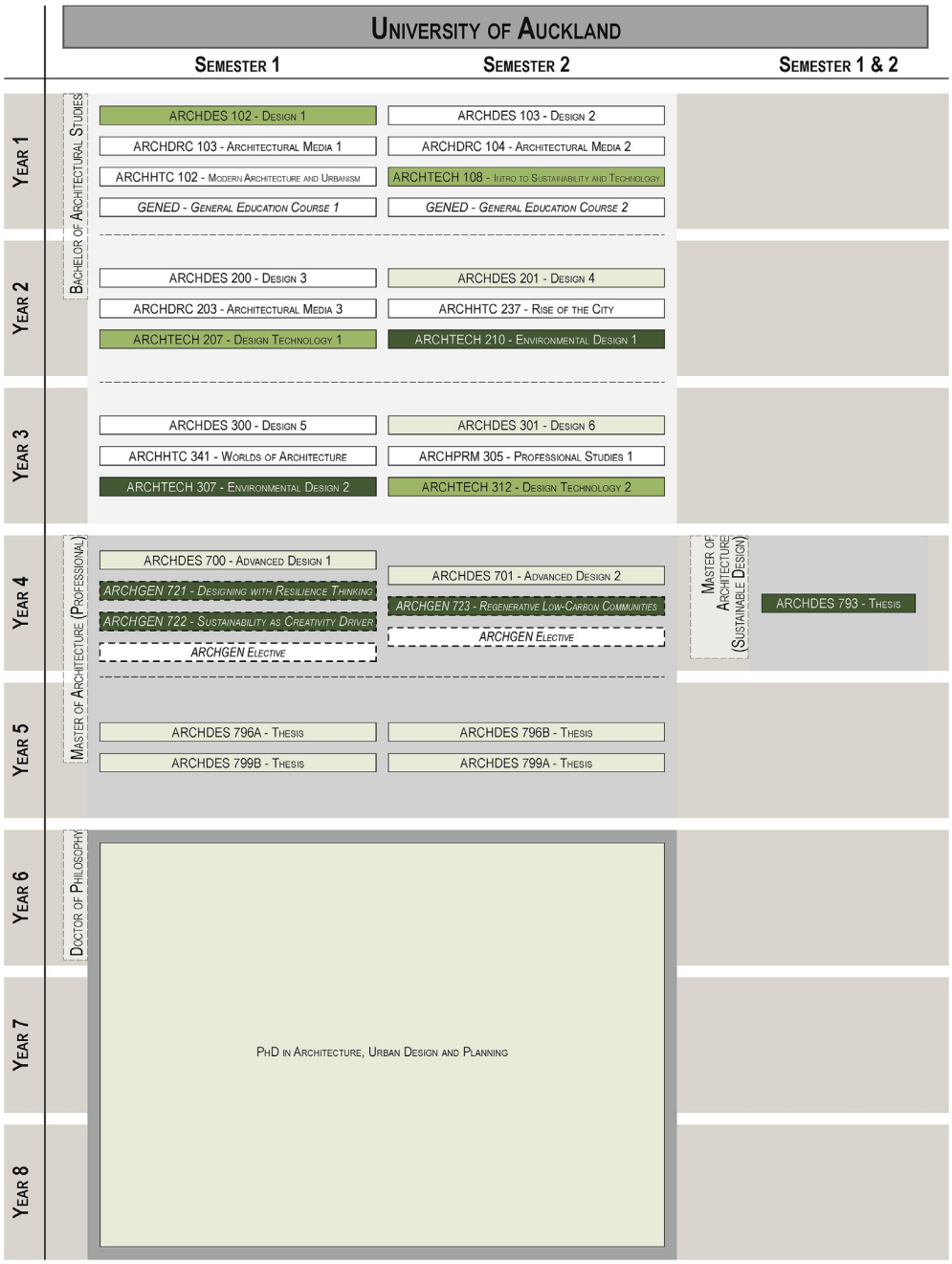
Approved by the University of Auckland Human Participants Ethics Committee on 10 December 2018 for three years. Reference number 022300.

Approved by the University of Texas at San Antonio Institutional Review Board (IRB). Reference number 19-019E.

Appendix B. Supplementary data - Questionnaire

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.119237.

Appendix A1. - Architecture degrees at the University of Auckland



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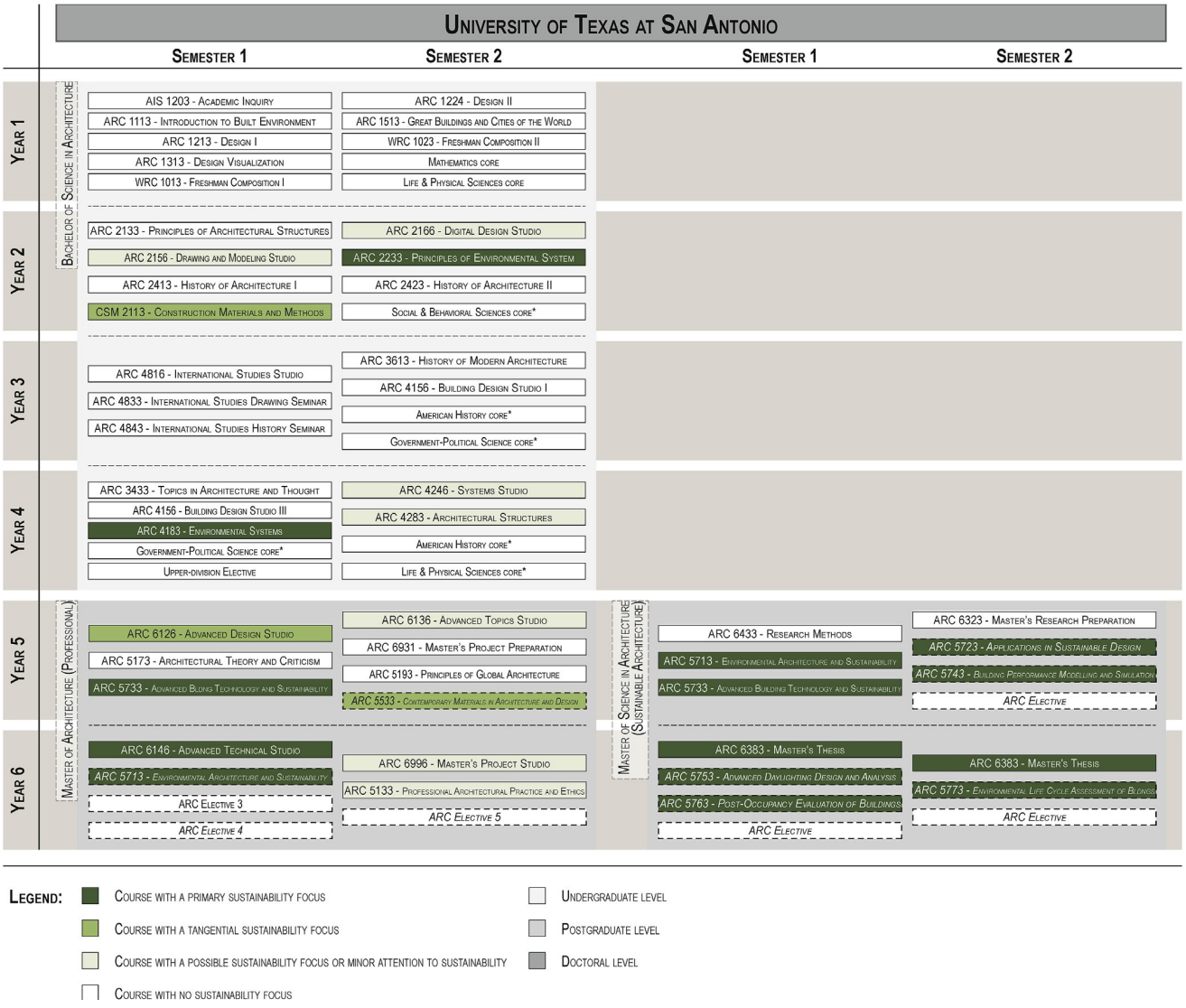
- COURSE WITH A PRIMARY SUSTAINABILITY FOCUS
- COURSE WITH A TANGENTIAL SUSTAINABILITY FOCUS
- COURSE WITH A POSSIBLE SUSTAINABILITY FOCUS OR MINOR ATTENTION TO SUSTAINABILITY
- COURSE WITH NO SUSTAINABILITY FOCUS
- UNDERGRADUATE LEVEL
- POSTGRADUATE LEVEL
- DOCTORAL LEVEL

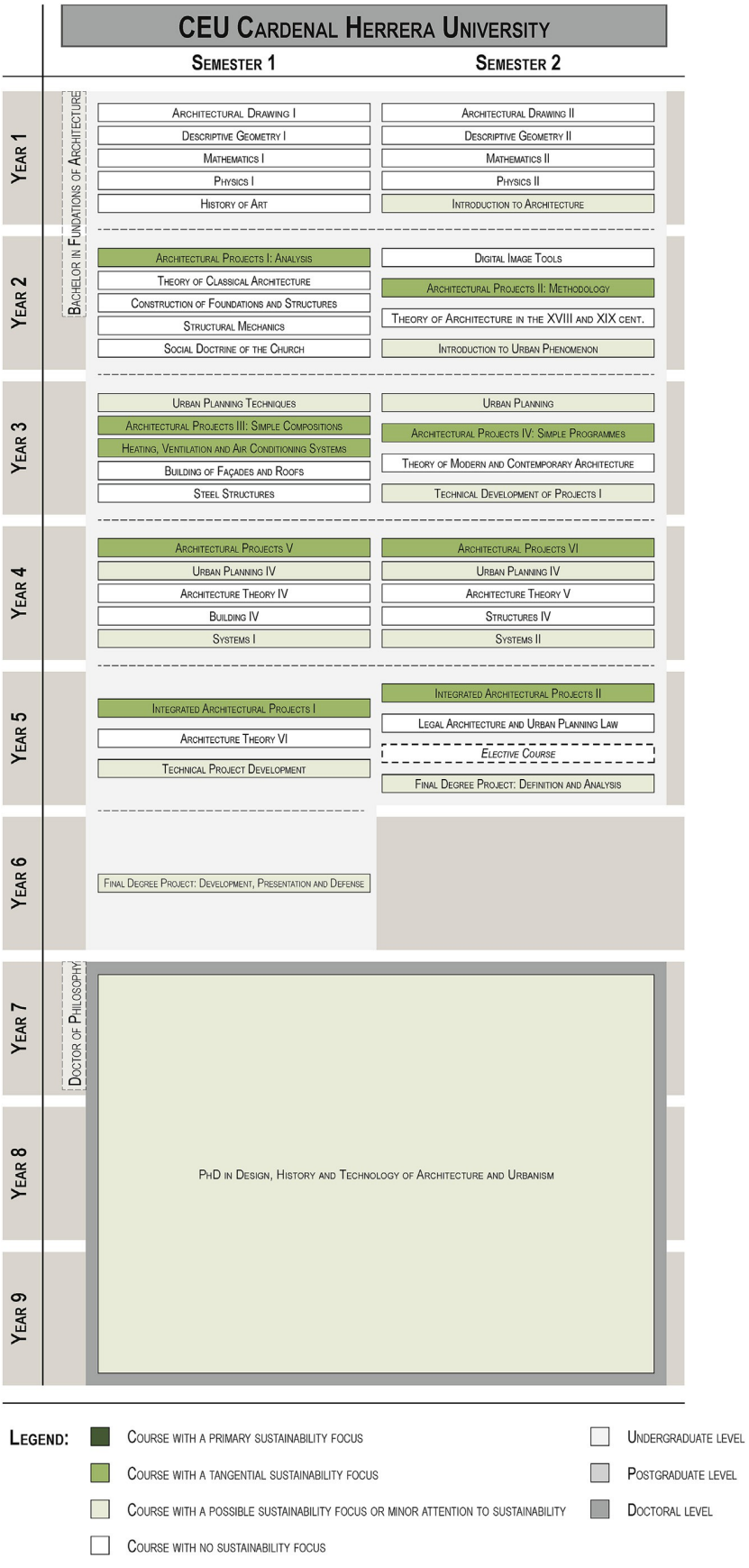
Appendix A 1. Graphic representation of architecture degrees offered at the University of Auckland, New Zealand. Notes: i) Courses written in italic and with dashed border are optional selections among a wider pool of courses available to students on an annual basis; ii) (1) in 2019, the 3rd year of the BAS is still delivered according to the old structure, while the 1st and 2nd years are already offered according to the new structure. The new structure of the 3rd year will be offered from 2020; iii) ARCHDES 102e103 equal to 15 points; ARCHDES 200e701 equal to 30 points; iv) all ARCHHTC, ARCHDRC, ARCHTECH, ARCHPRM and ARCHGEN courses
equal to 15 points; v) ARCHDES 796e799 equal to 60 points; vi) only one elective seminar among ARCHGEN 721e723 can be chosen by the student and the second elective topic must be from another disciplinary stream (ARCHGEN Elective); vii) the Master of Architecture (Sustainable Design) is a research-based degree and does not lead to professional registration.

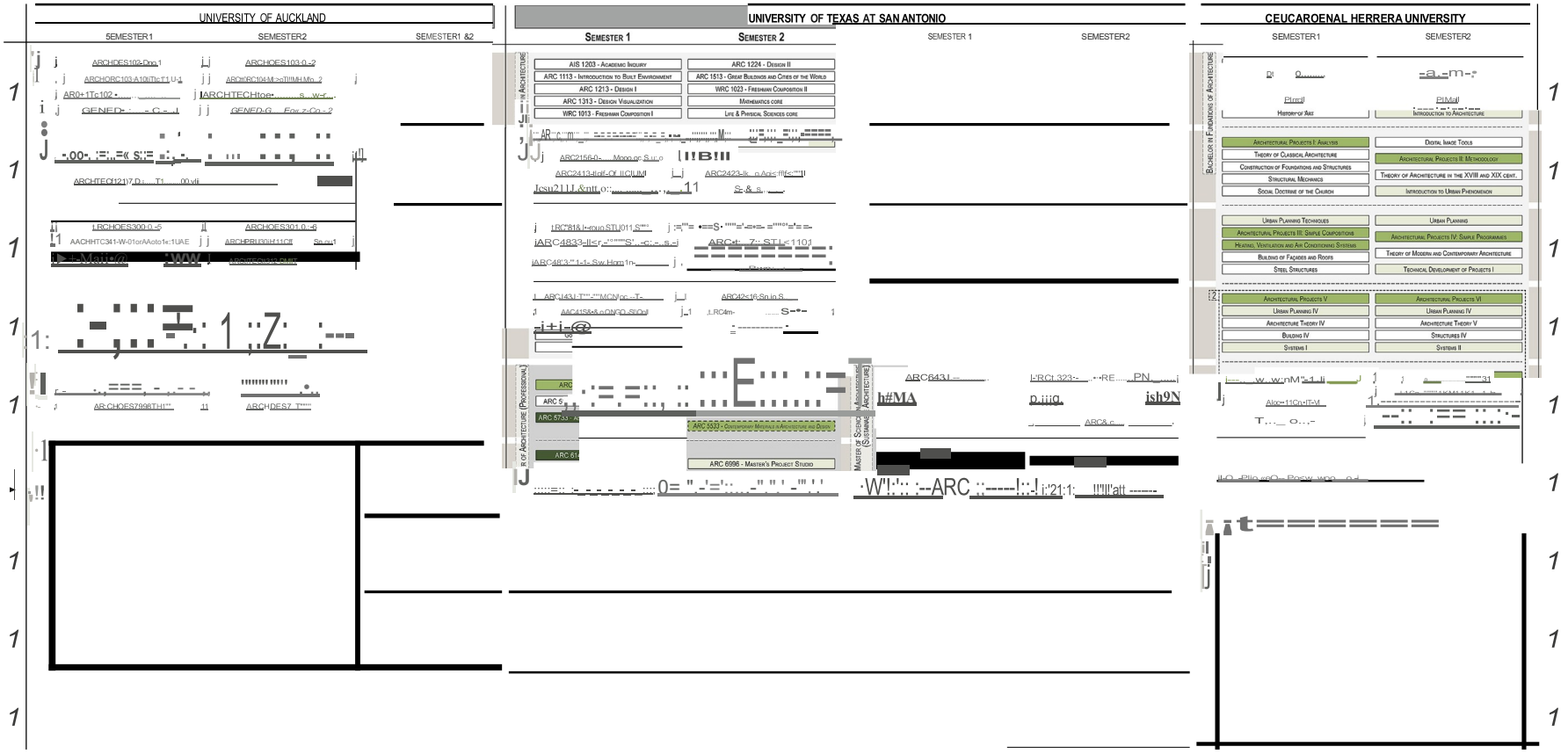
Appendix A2. - Architecture degrees at the University of Texas at San Antonio

Appendix A 2. Graphic representation of architecture degrees offered at University of Texas at San Antonio, USA. Notes: i) Courses written in italic and with dashed border are optional selections among a wider pool of courses available to students on an annual basis; ii) Courses with * are interchangeable and can be completed in any order. ARCH 2156 and ARCH 2166 are inter- changeable and can be completed in any order. During the 3rd year of the Bachelor of Science in Architecture, students are able to travel abroad either fall or spring semesters. Courses are allocated to the semester according to the semester of the study abroad period. In the Master of Science in Architecture (Sustainable Design), only 2 elective courses among ARCH 5723, 5743, 5753, 5763 and 5773 are to be chosen by the students and other 3 elective topic must be selected in consultation with the Thesis Committee Chair.



Appendix A3. - Architecture degrees at the CEU Cardenal Herrera University





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NOTES:

• Courses writteninitalicand with dashed border are optional selections among a wider pool of coorses avc1illable to studenIB on an annual basis.

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2. In 2019,lhe 4",5th and 6" years areslill deliveredaccordingto the old struciure of lhe 8A, while the 1•,2nd and 3,:1years are already offered according to thenew structure of 1heBFA. The new stmcture of the 4" and 5" years will pmgressively start from academic year 201912020.

ADDIT1ONAL INFORMATION:

• UoA: ARCHDES 102-103 equal\ to15 points; ARCHDES200-701 equal to 30 points; atl ARCHHTC, ARCHDRC, ARCHTECH,ARCHPRM and ARCHGEN courses equal to 15 points; ARCHDES 796-799equal to 60 points. Only ene elective seminar among ARCHGEN721-723canbe chosen bylhe student and the second elective topic must be lrom another disciplinarystream (ARCHGENElective). The Master of Architecture(Sustainable Design) is aresearch-baseddegree and does not leadto prolessional regis1ration

• UTSA: Courses wilh • are interchangeable and can be completed in any order. ARCH 2156and ARCH 2166 are interchangeable and can be completed in any arder. During the 3'" year of lhe Bachelor of Science in Architeture, students are able to travel abroad e;lher fall or spring semesters.Comses are allocatedto the semes1er according to the semester of the s1udy abroad period. In the Mas1er of Science inArchitecture (Sustainable Design),only 2elective courses among ARCH 5723, 5743, 5753, 5763 and 5773 are to be chosen by the students and o1her 3 elective tapie mus1be selected in consultationwith1he Thesis Commi11ee Chair.

• CEU: ArchitecturalProjectsoo Semester 1 equal to7,5 credits; Architectural Projects on Semester 2 equal to9,0 credits;Urbancourses equal to 6credits;Facilities (Heatinga Water systems) equal to 4,5 credits; Technical Development of Projectsequal to 9 credits. Coostruciion of theproject eQua1to9creditsandOptativesequalto3credits.FinalDeQreeandFinalMasterProjectseQualto30credits

Appendix A 3. Graphic representation of architecture degrees offered at the CEU Cardenal Herrera University, Spain. Notes: i) Courses written in italic and with dashed border are optional selections among a wider pool of courses available to students on an annual basis; ii) (2) In 2019, the 4th, 5th and 6th years are still delivered according to the old structure of the BA, while the 1st, 2nd and 3rd years are already offered according to the new struc- ture of the BFA; iii) The new structure of the 4th and 5th years will progressively start from academic year 2019/2020; iv) Architectural Projects on Semester 1 equal to 7,5 credits; v) Architectural Projects on Semester 2 equal to 9,0 credits; vi) Urban courses equal to 6 credits; vii) Technical Development of Projects equal to 9 credits; viii) Construction of the Project equal to 9 credits; ix) optional courses equal to 3 credits; x) Final Degree and Final Master Projects equal to 30 credits.

Appendix A4. - Comparison of architectural curricula of the three Universities.

Appendix A 4. Representation and comparison of the architectural curricula comprising sustainability subjects offered at the University of Auckland, at the University of Texas at San Antonio and at the CEU Cardenal Herrera University.

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