TEACHING ASSEMBLY FOR DISASSEMBLY; AN UNDER-GRADUATE MODULE EXPERIENCE

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ABSTRACT

This paper is about the experience of teaching Assembly for Disassembly to fourth year architect students within the module of sustainable design. When designing a sustainable building one should take into consideration the fact that the building is going to be demolished in some years; thus the materials should be assembled in such a way so that the building is not just demolished, but disassembled in a practical way, so that its items and materials can be reused or at least be recycled in other buildings or products or be decomposed. Yet, the structure should be safe during its lifetime. With this technology, the building's sustainability spans also to its "grave". In this paper the methodology for teaching students how to design for the disassembly of buildings is presented. Apart from the respective lectures, the fourth year students have been asked to design a small home for a homeless person, following, apart from bioclimatic design and the zero-CO_2 building design, an "assembly for disassembly" design. They have also been encouraged to use, apart from conventional building materials, materials that could be collected from municipal waste, provided they have a small environmental footprint. Frequent tutorials are made during this project. Different groups of students have followed different concepts in their design; some students have focused on the assembly for disassembly of a home from municipal waste, others from construction materials, while others, apart from assembly for disassembly, have also taken into consideration the movability of their design as well as its incorporation in the urban tissue. The results and the conclusions are presented in this paper.

KEYWORDS

Assembly for disassembly; sustainable construction; sustainability; education; building materials; design.

1. INTRODUCTION

When teaching sustainability to architects, students should be able to practice sustainable architecture both in a holistic and in a serialist way by the end of the module, so that they are able, according to Race (2001), to both "comprehend" the issues, so that they can make decisions, and also to "operate" certain tools (algorithms, sun charts etc.). Apart from energy and water savings, the use of ecological materials, as well as the use of passive solar systems and the implementation of Renewable Energy Sources, students have to be introduced to the Life Cycle Analysis of buildings, should they design sustainable buildings and settlements. Assembly for DISAssembly (ADISA) is one of the most prominent techniques to designing sustainable buildings, which will not form building waste, but, if demolished properly, their materials and items can be reused, or at least recycled or decomposed. ADISA, as a sustainable construction technique, is taught during the spring semester module "Sustainable Design II", preceded by the winter semester module "Sustainable Design I" to the fourth –year students of the five - year course in Architecture at the University of Patras, Greece. During the academic year 2012-13 further emphasis has been placed on ADISA, so as to teach the students that apart from the ecology of materials, the bioclimatic design and the low energy and water consumption as well as the low waste production of buildings, they cannot be holistically sustainable, unless their disassembly has been put into consideration since their design, putting into consideration the Life Cycle Analysis of the design and the structure. As ADISA is not so often part of the curriculums of sustainable design modules, the pedagogical approach that has been followed for teaching ADISA to undergraduate architecture students and its results are presented in this paper, hoping to open up a dialogue on the methodology of teaching ADISA to undergraduate architect and engineering students.

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2. TEACHING METHODOLOGY

As one learns through practice and assessments should be oriented towards learning (Gibbs and Habeshaw, 1992; Webb and Willis, 2010), emphasis is given on the students' practice on learning how to design for Assembly for Disassembly. For this reason students are asked to perform a group assignment (two to four people), which makes up to 40% of the module's final mark and to design an ADISA small shelter for a homeless person, which could be easily placed, either as a stand-alone shelter or as a group of shelters in the city of Patras public spaces (squares, parks), providing zero-CO_2 emissions, water savings and zero-waste, healthy, ergonomic living space for the homeless. They are also asked that the shelter or group of shelters are placed in such a way so that they do not form ghettoes nor encourage depravation in the public space. The structure has to be earthquake-proof and easily assembled and disassembled. Students have been encouraged to provide designs that could be constructed by unqualified people (e.g. by the homeless themselves) and be easily deconstructed, with reusable members, so that they are not left behind when the homeless have found a proper home, as had happened with the "isobox" shelters of the 1999 earthquake homeless in the greater area of Athens. Budget limitations have not been placed.

2.1 Description of Teaching

The respective lectures explain the importance of reducing building waste, as, before the country's economic crisis they made up to 31% of the municipal waste (Dimoudi, 2006). The lectures focus on an introduction to the Life Cycle Analysis of buildings as well as on the principles of ADISA, as have been put forward by Burge (2001). The rationale of "reduce-reuse-recycle" is reminded in every step of the design and ADISA is thoroughly explained; it is made clear that when designing, from blocks of buildings to structural details, one should bear in mind that building materials should directly be reused, so as to lower building waste. Thus, the building's separate layers should be technically separated (e.g. piping separated from walls), each layer should be easily disassembled with simple mechanical strength and that standardised, mono-material components should be used, so as to encourage reusing. In this way, ADISA constructions can be easily separated into identical components and materials during demolition, ready to be useful components in another structure and not pile up in the municipal waste. The "joke" used during the lectures, to alert the students, is the comparison of ADISA buildings to LEGO structures most of the students made when they were kids.The ecology, embodied energy, reusability and recyclability of building materials is also presented thoroughly, covering all the building layers and the notion of the Life Cycle Analysis is put forward for many building materials. Respective notes are also given to students on the module's electronic platform (e-class).

As the lectures also focus on the importance of reducing building and municipal waste, the rationale and the work of architect Michael Reynolds is presented (Reynolds, 1993) and a documentary is also shown to students, the "Garbage Warrior", where Reynolds' work and its application in providing temporary shelters in earthquake-struck areas is presented (Hodge, 2007). For pedagogical reasons, not the whole documentary is shown, but mostly the parts that focus on the materials and structures from municipal waste, rainwater harvesting and waste management. During the documentary show, comments are made by the lecturer and further information is given to the students where they can watch the whole documentary, if they wish to.

During the lectures, examples are also given on ADISA buildings, especially from Roaf et al (2007) and Burge (2001). Yet, not such great detail is presented from the beginning, especially regarding construction details, so as to encourage students to think out of the box and come up with their own ideas about the materials they chose and whether they use construction materials or municipal waste for their assignment. Although there is a plethora of information on how to design for the homeless, with both municipal waste and structure materials, from both Universities and practitioners (e.g. Azari et al, 2009; D'Apolito, 2012; Meinhold, 2013 etc.), this information has not been provided to the students, so that they mostly focus on ADISA and either make up their own structural details or research. The structural details are further examined during the assignment tutorials.

The lectures are also followed by class exercises, asking the students to design structural ADISA details, with materials of their choice and to discuss whether the use of municipal waste could be used for the construction of safe and healthy buildings, especially during the recent years that the country is under great economic depression. The class exercises are corrected and handed in to the students during the following class. They are marked for the participation and not for their content, as students have just been introduced to the respective concepts and a negative mark might be discouraging and unfair.

Great emphasis is given on the tutorials of the assignment. All members of the group are asked to be present during the tutorials, where their sketches, drawings and ideas are reviewed, discussed and corrected. Apart from ADISA, the choice of materials, the bioclimatic design and the zero environmental footprint of the structure are discussed. About six tutorials have occurred for this assignment, providing guidance through every step of the students' designs.

There is also a mid-term presentation of the assignments, where all students can see and comment on their colleagues' projects and further comments are made by the lecturers.

3. RESULTS

Regarding the first class exercise (the ADISA structure details), some students manage to come up with efficient ADISA structural details, while for others, influenced by their existing knowledge on concrete – brick structural details, it has been harder to think differently just by listening to lectures. Regarding the second class exercise (the discussion on the use of municipal waste as structural materials), there is a number of students who think that transforming municipal waste into building materials would help provide shelters and generally, less expensive buildings during the economic crisis and be a solution to the management of municipal waste, while there is a group who is skeptical that this would be used only for the poor people's shelters and housing, leading to more social depravation and unfairness. It is interesting to mention that the latter group of students does not incorporate municipal waste in their designs, but prefer to use building materials for their ADISA shelter.

Tutorials have been crucial to further understand ADISA; at the beginning it had been very hard for students to think about structures where the finishing layer might not be plaster and that piping and electrical wires would not be incorporated inside the walls. Examples of primitive architecture, and the work of Kahn (1973) and Triantafyllou (2010) have been put forward, as well as the lecturer's ADISA construction details (these proposed towards the last tutorials), so as to help them perceive materials that are used in structures in a different way. The space's ergonomics, as a technique of minimising the use of materials, as well as the consideration of sun and wind (which had also been a priority in their designs during the previous semester) and water savings are also put forward during the tutorials, as well as the aesthetics and the shelter's relationship with the urban space.

The presentation has also helped the students to put their ideas together and be able to justify them. During the presentation, a lot of comments have been made on how the materials and the elements are combined together and also on the aesthetics of the proposals, as well as on their incorporation in the urban fabric, so as not to end up in ghettoes, on which the next tutorials after the presentation focus. Apart from that, some students whose assignments had not advanced that much up to the presentation day seemed to be inspired by the presentations of their colleagues; some of the ideas that had been discussed during tutorials and encouraged during the presentation have been implemented to the designs of groups which had not been so eager to participate in the tutorials.

In the assignments that have been handed in, 62% of the main materials that are used are structural materials while 38% reclaimed municipal waste. Most of the municipal waste is combined with structural materials (e.g. timber or steel frames), while 14% are more radical designs and use only municipal waste as their primary structural source, incorporating also fishing cords and nails to joint reclaimed municipal waste so as to form the shelter. In all designs, no gluing takes place between the different layers of materials; only nails and screws. Some designs have also used paper or clay to join together plastic or glass bottles and fewer cement, while other designs have left more air losses through the bottles, so as to make disassembly easier (Figure 1 a and b). No plastering is incorporated in any of the designs. The different layers of the structure are clearly separated (structural frame from walls, insulation from walls, or walls that need no insulation are used, separation of walls from windows, separation of drainage, piping and electrical wires from walls etc.), while some designs have used standard units to form the shelter.

The frequency with which the construction materials or the municipal waste are used is shown in Table 1. As can be observed in the following table, wooden pallets are the most frequently used municipal waste (25% when compared to other municipal waste, 9% when compared to all the main materials used). Students use them as flooring, wall and roof materials, insulating them with either paper waste or insulation of plant origin (kenaf, cotton, cork or straw). A lot of the designs have used the wooden pallet as a standardised ADISA material (Figure 3b), the dimensions of which make up the structure (both floors and walls), making it possible to reuse these items either as pallets or as structural or furniture materials, after the shelter's demolition. Glass bottles are frequently used (19% when compared to municipal waste and 7% when compared to all the main materials used), many times in relation to wooden pallets as openings (for solar gains, cross ventilation and natural light) and also either joint together with paper pulp, cement or cob. Regarding structural materials, most students have preferred to use timber in their structure either as frames and / or as walls (23% when compared to other structural materials and 14% when compared to all the main materials used), while double-glazed, pure glass with aluminum or timber frame replaces the reclaimed bottles for solar gains and natural daylight (22% when compared to other structural materials and 14% when compared to all the main materials used). Some students also use cob / rammed earth as their main construction material (7% and 4%, respectively). Although cob as well as cement may not be the most prominent ADISA materials, students who have used the first one, argue that it can be easily demolished and decomposed. Students who use rammed earth, as well as students who use reclaimed materials are very sensitive about the costs of such a structure, making the decision, that with their design a low budget shelter can be created by the homeless themselves, while other students have decided that the Municipality of Patras or the Greek Authorities will provide the homeless with the appropriate budget to create a quite high-tech shelter, with photovoltaics and all the necessary facilities.

Table 1. Main materials used in the ADISA assignments and the percentage of their use (a) per all the main materials and (b) per construction materials and municipal waste, respectively.

	Materials used	Percentage of use of materials per total	Percentage of use of materials per construction materials or municipal waste, respectively
Construction materials	Cob / Rammed earth	4%	7%
	Paper	3%	5%
	Metal frame	9%	15%
	Cork	2%	3%
	Timber	14%	23%
	Thermal insulation (kenaf, cotton)	6%	9%
	OSB or SIP panels	3%	5%
	Straw and strawbales	2%	3%
	Metal parts (reused)	2%	3%
	Glass with aluminium or timber frame	14%	22%
	Paper	1%	1%
	Concrete	1%	1%
	Sand	1%	1%
Municipal waste	Plastic bottles	2%	6%
	Glass bottles	7%	19%
	Wooden pallets	9%	25%
	Plastic membranes	6%	15%
	Fabric	6%	15%
	Paper tubes, cartons and newspapers	4%	12%
	Metal tubes	3%	8%

The majority of the shelters (69%) are designed so as to be combined with other shelters and be connected to facilities buildings (existing municipal buildings or new ADISA buildings); where toilet and kitchen facilities are supplied, while 31% of the designs refer to stand-alone, autonomous shelters. The students who prefer the first solution follow the rationale that less materials should be used in the shelter and that waste should be treated centrally, while the students who prefer the second solution, put forward the idea that the new-homeless people should be able to survive independent from a central authority that might not finally work out. In many of the non-autonomous shelters, no shewing systems are necessary and in some no electricity facilities either; night light is provided through photovoltaic table lamps. In the autonomous shelters piping is either detached from the walls and is visible to the interior, while in other designs, more bold about the economic costs, timber frames cover piping and electrical wires. Many of the autonomous designs use rainwater harvesting to cover sanitary water needs, compost toilets for water savings, photovoltaic panels and solar panels for the production of electricity and sanitary hot water, respectively (Figure 1c).

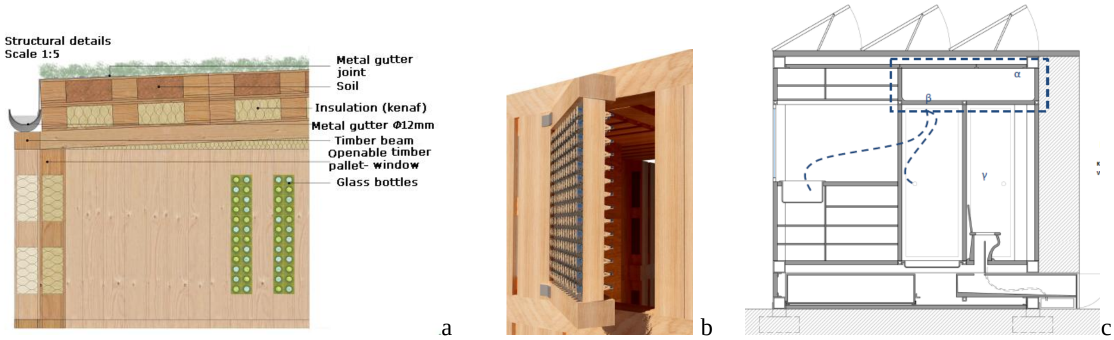

Figure 1. Structural details (a) of roof and walls, made of wooden pallets, openings made of glass bottles and water piping by the students V. Antonopoulos, A. Ioannou and V. Charalampopoulou (b) of a window, made of glass bottles and timber frame, which is nailed to the timber wall by the students F. Dimoglou, I. Theodosopoulou and S. Pavlidou and (c) rain water harvesting for sanitary water, compost toilet for water saving, photovoltaics for electricity production and solar panels for Sanitary Hot Water production in the project by the students G. Kourakos and Th. Svoronos.

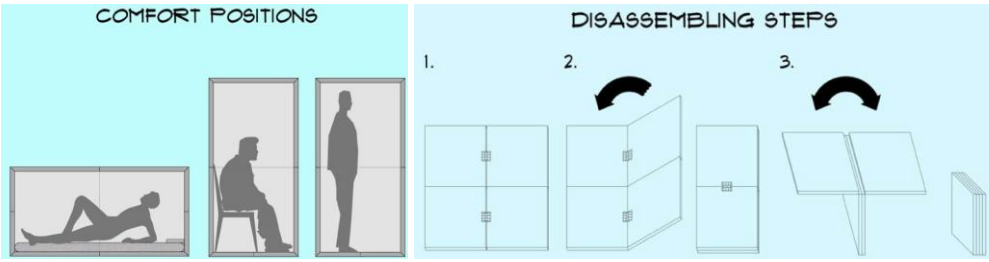

Figure 2. A transformable and movable minimal shelter by the students V. Paraskevopoulou and Z. Charalampous.

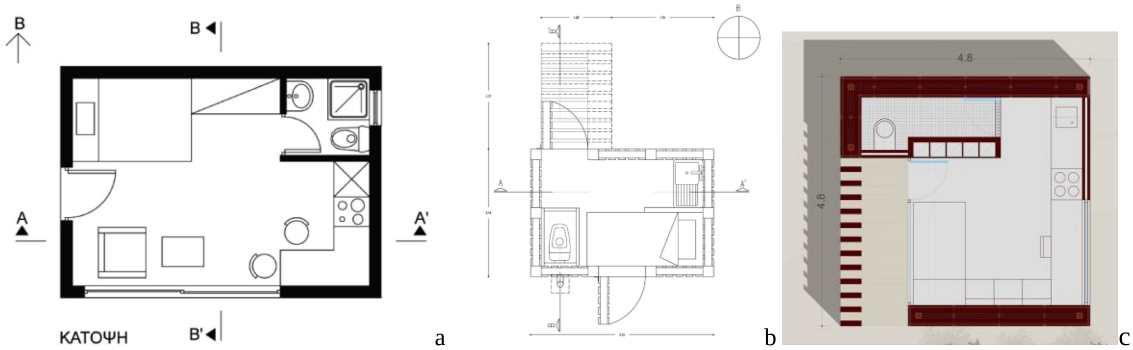

Figure 3. Stand-alone, fixed units by the students (a) A. Alafi-Andrikopoulou, N. Ioannidou, K. Papadioti and G. Tsantoulis (b) F. Dimoglou, I. Theodosopoulou and S. Pavlidou and (c) A.-P. Mourelatos and S.-P. Pandazopoulos.

Figure 4. Movability and transformations of a shelter by the students E. Vlachaki, A.-P. Dogani and M. Lafazani.

The design of the shelter varies from very simplistic, movable boxes (Figure 2) to autonomous and fully equipped, ergonomic, little homes (Figure 3a, b, and c). Many students (43% of the assignments) have put forward the idea that apart from ADISA, these shelters should be easily disassembled so as to be moved to another place, either in the simplistic form shown in Figure 2, or in more sophisticated structures with openable and movable members, as the one presented in Figure 4.

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Most of the designs have oriented the shelters to the south, so as to achieve solar gains either through direct gain or other passive solar systems, mostly Trombe wall. Eastern, western and northern openings are kept to a minimum in most of the designs, used for ventilation and day-light, if necessary. External shading devices, either movable or permanent, from fabric or timber are placed in the southern, eastern and western openings. Solar winter penetration and summer shading have been calculated for the geographical latitude of Patras (38^o) (Figure 5a and b). Taking into consideration the wind speed and direction from the meteorological data of the city of Patras, the type of the occurring air flow is estimated, in relation to the proposed geometry. The ventilation of the occurring open and interior spaces is thus examined (Figure 5c). Most designs have incorporated night ventilation as the main cooling strategy, which is achieved through cross ventilation from the openings, which are either glass (structural or waste) or plain timber movable frames, while some have considered vertical ventilation from removable openings on the roof. 11% of the designs have also placed green roofs on the top of the shelter so that the microclimate around the shelter is altered in a positive way and also so that food production can occur within the shelter.

The aesthetics of the shelter and its relation to the urban environment have also been very crucial. Some students come up with more classic relationships between shelters and the open space, allowing for large areas between the shelters, where air can flow and people can move (Figure 5), while others have considered their shelters to be a living sculpture (Figure 6), adding up to the aesthetics of the urban space.

In most designs, photovoltaic panels are used for the production of electricity (45%), as shown in Table 2. Solar panels are also used for the production of sanitary hot water or for space heating (31%). Geothermal pipes for space heating and cooling is used only by 3% of the assignments, while rainwater harvesting, water recycling and compost toilets are used by the majority of the students (54%, 51% and 46%, respectively), especially in the stand-alone units.

Table 2. Technology for electricity, sanitary hot water, space heating / cooling (apart from solar energy and ventilation), water collection and savings used in the assignments.

Technology	Percentage of its use in the assignments
PV panels for electricity	45%
Solar panels for SHW and space heating	31%
Rainwater harvesting	54%
Water recycle	51%
Compost toilets	46%
Geothermal pipes	3%

3.1 Lessons Learnt

Through this process, it has been found out that the most important pedagogical tool for the achievement of learning ADISA, apart from lectures, has been the assignment and the respective tutorials. Students who have participated in all the tutorials, where their designs are thoroughly discussed and advice is given on how to improve their ideas have been able to hand in high quality work. Students who have been less eager to participate in the tutorials have come up with more simplistic ideas, some of which have also been presented in this paper. The mid-term presentation, acting also as a way of communicating ideas, seems to help students, especially those who have not worked their project so intensively up to then, to get engaged in the assignment and get inspired by the ideas their fellow-students had come up with. Lectures, notes, documentary show and class exercises have also been helpful, but not as much as asking the students to think and do it themselves through the assignment and the student-lecturer communication through the tutorials for the achievement of “thinking out of the box” ADISA designs.

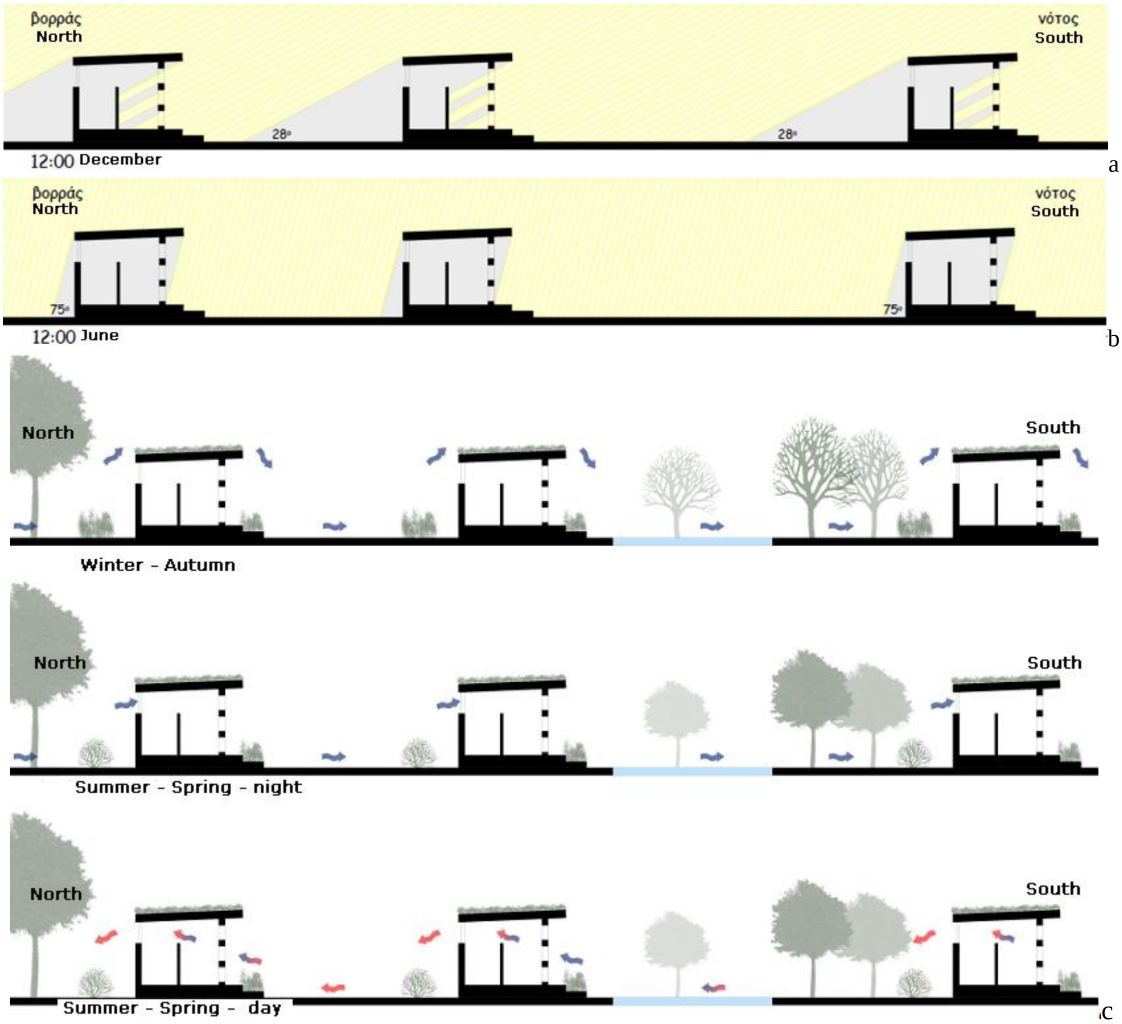

Figure 5. Noon sun at the southern façade of the shelter (a) in winter – solar gains and (b) in summer – external shading and (c) ventilation strategy and type of air flow during the different seasons by the students V. Antonopoulos, A. Ioannou and V. Charalampopoulou.

Figure 6. ADISA shelters placed so as to form a living sculpture in an urban park in the city of Patras by the students E. Bagianou and K. Papathanasopoulou.

4. CONCLUSION

Through the intensive tutorials on the assignment, the lectures, the class exercises and the presentation, the submitted work has been, in most cases, of high quality, especially those produced by students who participated throughout the whole process (lectures, class exercises, all the tutorials and presentation). The students have been given the freedom to choose the origin of the materials, either from typical structural materials or from municipal waste as well as the type of the design, from permanent to movable shelters, from simplistic to sophisticated designs. The assignment's marks range from 6 to 10 (out of 10) with an average of 8.11. Although it has been hard at the beginning for students to comprehend ADISA and to rethink about the structural details they had learned during their 3rd year of studies, through the collaboration of the lecturer and the students, as well as through their collective work, the majority manages to incorporate ADISA in their sustainable design, in both a comprehensional and operational level. After this experience, the students are able to both set the sustainability goals of their design and take the appropriate decisions and also to design the details that lead to the desirable result. One of the students, A.-P. Mourelatos, has won a national students competition for the visitor centre of the Stavros Niarchos Park (the design selected by Renzo Piano), designing a "recyclable" building (SNF, 2013).

As our educational system tends to lead to more standardised ways of thinking and designing, one of the hardest parts of this assignment has been to make students think out of the box and apply Assembly for Disassembly either with conventional building materials or with reclaimed municipal waste, making their own decisions, designs and structural details. As new environmental problems arise every day and the architects and the engineers of the future should be able to challenge them quickly, apart from ADISA, students should be asked more frequently to think out of the box through our pedagogical approach.

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