THE IMPLEMENTATION MODEL OF INTEGRATING THE THREE SUSTAINABILITY ASPECTS INTO THE UNDERGRADUATE ARCHITECTURAL DESIGN STUDIO

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ABSTRACT

The concept of sustainability in design is meant to ensure that the product of the design is in harmony with humans and nature by taking into consideration the three aspects of sustainability: environmental, social and economic. The objective of this experiment was to integrate the three aspects of sustainability principles into the architectural design studio to train future architects to be able to design sustainable buildings. The study aimed to create an integration method that could be validated through the junior students' work in the innovative Sustainable Architecture Design Studio (SADS) at Izmir Institute of Technology. The impact of the pedagogy on the students' ability to integrate sustainable design principles into their projects was measured through the evaluation tools formulated for this purpose by the instructor. Further, the students' feedback through course evaluation, questionnaire, and colloquium at the end of the term was used to assess the method. The findings of this research demonstrated that the innovative studio pedagogy and teaching method were successful in integrating the sustainable design elements into design studio projects, while the level of sustainable elements integration was 68%.

KEYWORDS

architecture education, architecture design, design studio pedagogy, sustainability, sustainable design

INTRODUCTION

The architectural education model underlines three main themes: the first concerns the behavior aspect were the personality and character of an architect is shaped; second concerns acquiring knowledge; and third concerns developing the skills that students need to be a good architect (Bakarman 2003). While architectural design education has three variables that play a significant role: studio environment, the communication method between instructor and student, and the teaching approach and studio management (Al-Mogren 2006); it is successful architecture studio courses that integrate the practice of design activity with all other coursework and educational experiences. Design is a product of creativity, while creativity means seeing a relationship

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between new information and a previous experience to develop a fresh combination out of this perspective (Kahvecioglu 2007) (Canaan 2003) (Aichholzer et al. 2018).

There is a need to adopt new principles to improve architectural undergraduate education, which can be used to help the integration of sustainability principles into the design studio. These principles are those that encourage contacts between students and faculty, develops reciprocity and cooperation among students, uses active learning techniques, gives prompt feedback, emphasizes time on tasks, communicates high expectations, and respects diverse talents and ways of learning (Chickering and Gamson 1987) (Riley, Grommes, and Thatcher 2007).

If the architectural design professions are to remain pertinent, architectural design education must completely integrate sustainability into the curriculum's pedagogy to tackle the current and emerging issues facing our society (Walker and Seymour 2008). There is a unanimity among architectural schools of the importance in creating a sustainable architectural awareness and consciousness within students who will be the future generation of architects (Bala 2010). Furthermore, the jury system should not only focus on criticizing the design project but also should embrace the strengthening of the learning process and measure the acquisition and application of knowledge.

Sustainability is defined in terms of continuity and maintenance of resources (Williamson, Radford, and Bennetts 2003). Sustainability embodies the idea that humans can consciously contribute to meet the needs of the present generation while ensuring that the needs of future generations are not compromised. It is an interdisciplinary concept in character, which demands participation by the community from all levels, looking to maintain a balanced ecological, economical, and social system. Furthermore, sustainability is about creating an efficient system that manages to use and distribute natural resources (Benkari 2013) (Skabelund et al. 2010).

Sustainable architecture is a revised conceptualization of architecture to answer numerous contemporary concerns regarding the effects of human activity. The key to architectural sustainability is to work with, not against, nature; to comprehend, sensitively employ, and at the same time avoid damaging natural systems (Williamson, Radford, and Bennetts 2003). The building industry demands graduates and practitioners who can respond to the challenges of climate change with the competence of sustainable design (Altomonte et al. 2012).

RESEARCH PROBLEM

- Outdated pedagogy of architectural education focuses mainly on the form and art as well as the separation between technical courses and design studio (Lofthouse 2013) (Heylighen, Bouwen, and Neuckermans 1999) (Utaberta, Hassanpour, and Usman 2010).
- The design courses focus on creating an individual character, not on training to work with other related disciplines (Buchanan 2012b) (Yu 2014) (Lofthouse 2013).
- Architectural schools use digital technology as a CAD tool. Digital technology should be fully integrated into the whole design process (Yu 2014).
- The studio instructors do not possess the required knowledge base nor the practical professional experience (Altomonte, Rutherford, and Wilson 2014).
- There are ambiguous definitions of sustainable architecture as well as the lack of experts in this area (Taleghani, Ansari, and Jennings 2011) (Wainwright 2012).
- There is a lack of clear teaching pedagogy and instructive teaching tools for sustainable design studio (Mohamed and Elias-Ozkan 2019) (Mohamed 2020).

RESEARCH OBJECTIVES AND AIMS

The objective is to integrate the three aspects of sustainability principles into design studios to produce a sustainable design solution for the student's architecture project. The study aims to:

- Create an integration method
- Test the integration method
- Test the method's impact on the student learning level and the level of integration with the designed projects

The goal of the research is to provide an innovative *studio structure* and a novel *Sustainable Architecture Design Studio (SADS) model* for architectural educators, planners, studio teachers, who can be adopt it for sustainability-oriented curriculum development and integration.

METHODOLOGY

The implementation of the three aspects of sustainability in a design studio is meant to create a design studio education pedagogy that leads to a teaching method that makes the maximum use of the technical and theoretical courses in the project design process. The created pedagogy tended to focus on learning by practicing rather than by more passively acquiring information. The following references the methodology guides:

- Flipped learning classroom principle (Liu, Zhang, and Fan 2013)
- Embracing a deep learning approach for principles and practices of sustainability (Kevin 2003, O'Brien and Sarkis 2014, Sarhan and Rutherford 2014)
- The three principles of Ecole education: freedom, competition, and variety (Drexler 1977, Carlhian 1979, Chafee 1983)
- Charrette design studio technique (Walker and Seymour 2008, Pernice 2013)
- Constructivist design studio concepts (Jonassen 1994, Kurt 2012)
- Learning pyramid principles that supported deep learning (Wood 2004)
- The Bauhaus prime education objectives depended on integrating theory and application (Whitford 1992)
- The recommendations of the first and second experimental of Sustainable Architectural Design Studio (SADS) (Mohamed and Elias-Ozkan 2019) (Mohamed 2020)

These references reflected the framework for the new structure of design studio pedagogy and the implementation of digital technology. The research is a quantitative and qualitative method type that provided various ways to evaluate and assess the new sustainable design studio pedagogy and the integration success level in students' designed projects.

MATERIAL AND METHOD

SADS was carried out at the Architectural Department of the Izmir Institute of Technology (IYTE), in Turkey. There was a team of two instructors who conducted the design studio, supervising all students with the help of one teaching assistant. The studio class had twelve working hours per week. The research was implemented in the third-year design studio (AR 302 Architectural design IV) in the spring term of 2016, with 25 students (12 females and 13 males). The design studio pedagogy was based on 8 teaching/learning techniques that are presented in (Table 1). These are Learning by doing; Learning by teaching others; Learning

TABLE 1. SADS's instructor teaching elements of the experimental studio.

No.	Learning Technique	Teaching Elements of SADS Spring 2016
1	***Learning by teaching others.***	One case study was presented by each student (25 case studies). Finished in the first 5 weeks. **Case studies presentation had 5% of total class grade.**
2	***Practice by doing and group discussion.***	Students were required to write the project program individually then in a small group of three then in a group of eight. The project size was about **7000 m^2**
3	***Practice by doing.***	Students were required to construct study models during the project design development process (**6 models**) with various scales and material types.
4	***Deep learning***	Weekly panel reviews were conducted (**12 panel reviews**) in two formats:
	Group discussion	A) Group discussion of the design process and project development were conducted.
	Learning by demonstration	B) Students criticized each other's project by asking each student to present his/her project to the group
5		Three technical trips to:
	Practice by doing	A) The project site and surrounding area.
	Learning by demonstration	B) Existing exemplary projects out of town (Bodrum, Turkey)
	Learning by demonstration	C) Existing exemplary projects in town (Izmir, Turkey)
6	***Practice by doing***	Instructors conducted weekly charrette design assignments during the design process (**11 assignments**)
7	***Practice by doing***	Various digital technologies were used throughout the deesign process:
		A) Conceptual design period; climage consultant and Sketchup.
		B) Design development period; Revit, Auto CAD, and Sketchup.
		C) Design evaluation peroid; Rivet (Energy) and DIALux evo (Light).
		D) Final drawing and presentation; Rivet, Auto CAD, 3D Max, Sketchup, and DIALux evo.
8	***Public interest/ immediate use practice***	Project owner(s)/user(s) were invited to discuss the project and provide presentation and workshop (**2 visits**).
9	***Learning by demonstration***	Biweekly Outside expert(s) were invited for workshop (**5 workshops**).
10	***Practice by doing***	A) Instructors assigned homework related assignment ahead of each workshop studio (**6 assignments**)
	Learning by demonstration	Instructors conducted individual and small group desk critics (**15 desk critics**).
11	***Learning by visual, audio, and lecture***	Class instructors offered lectures about the project topics that included visuals and audios materials focusing on environmental and economical and social aspects of sustainability (**15 Lectures**).

TABLE 1. *(Continued)*

No.	Learning Technique	Teaching Elements of SADS Spring 2016
12		Juries:
	Learning by demonstration	A) Instructors conducted midterm juries (**3 midterm juries**) including outside guest.
	Learning by teaching others	B) Instructors hosted a final jury that included Izmir Municipality representative, the University Rector, experts, and academic members.
	Learning by demonstration	C) Instructors conducted role-play jury and student-led jury after third midterm jury.

by demonstration; Learning through audio-visuals/ lectures; Deep learning; Practice by doing; Group discussions; and Integrating public interest. All steps of the teaching method were included in the class syllabus, studio timetable, project program, grading system, and jury evaluations. The three sustainability aspects, i.e. environmental, economic, and social were considered for the experimental SADS studio. The term was quartered into time modules system, i.e. four weeks for the conceptual idea, four weeks for project development, four weeks for materials and testing, and two weeks for finishing and presentation, while each period ended with an open jury. This time module enabled students to focus on the design process and not only on the final design product.

SADS OUTCOME

The SADS's 100 points were divided into 40 points for evaluating the design process workload performance along with the term. While the other 60 points were for finished project evaluation of which 50% was dedicated purely to the design aspect and 50% for the degree of implementing the sustainability principles in the design project. The grade load distribution was designed to reflect the importance of the design process and the level of sustainable design elements integration in the student's project. The natural light simulation test was optional as a trial for this experimental studio.

Design Process Performance

Throughout the term, the design process work performance of each student was monitored, evaluated, and recorded according to the sub-items. The workload during the semester included group work, case studies presentations, individual assignments, technical trips to various sustainable architectural buildings, and midterm juries as shown in (Table 2).

Finished Product

After the final jury, instructors evaluated all projects following the grading system. The projects were divided into three groups: outstanding, satisfactory, and unsatisfactory according to the sustainability design elements number integrated into each project that includes the three aspects of sustainability aspects--environmental, social, and economic. Therefore, the total sustainable design elements were 28 as are shown in (Table 3). The benchmark evaluation for each category was as follows:

TABLE 2. SADS's grades earned by the students through evaluation stages of the design process.

No.	Attendance 5%	Site Analysis 5%	Assignments 5%	Case Study 5%	1st Jury 5%	2nd Jury 5%	3rd Jury 5%	Portfolio 5%	Design Process 40%
1	5.00	5.00	3.50	5.00	3.90	3.40	0.00	4.00	29.80
2	5.00	5.00	5.00	4.00	3.00	2.90	3.20	3.00	31.10
3	0.00	5.00	3.00	5.00	2.70	3.00	0.00	5.00	23.70
4	5.00	5.00	3.50	4.50	3.50	3.70	3.40	4.00	32.60
5	5.00	5.00	3.50	5.00	2.90	3.20	2.70	3.00	30.30
6	0.00	5.00	5.00	5.00	2.70	0.00	3.00	5.00	25.70
7	5.00	5.00	5.00	4.50	3.00	3.70	3.90	4.00	34.10
8	4.00	5.00	5.00	5.00	3.20	3.40	3.40	4.00	33.00
9	5.00	5.00	5.00	3.75	3.70	3.70	3.70	3.00	32.85
10	5.00	5.00	5.00	4.50	3.70	4.40	4.00	4.00	35.60
11	5.00	5.00	5.00	4.75	3.40	4.00	4.20	4.00	35.35
12	3.00	5.00	5.00	4.75	3.90	4.20	3.40	5.00	34.25
13	5.00	5.00	5.00	4.75	3.40	4.00	4.20	5.00	36.35
14	2.00	5.00	5.00	4.50	3.50	3.80	3.00	0.00	26.80
15	3.00	5.00	5.00	4.75	3.70	3.40	4.40	5.00	34.25
16	2.00	5.00	3.50	4.25	3.40	3.40	2.70	4.00	28.25
17	5.00	5.00	3.50	5.00	3.80	4.10	2.40	4.00	32.80
18	3.00	5.00	3.50	4.75	3.70	3.00	2.70	2.00	27.62
19	2.00	5.00	3.50	4.50	3.00	2.90	2.70	4.00	27.60
20	5.00	5.00	3.50	4.00	3.00	4.20	3.70	5.00	33.40
21	4.00	5.00	5.00	4.75	3.70	3.50	3.70	4.50	34.15
22	5.00	5.00	5.00	4.00	3.50	3.20	3.50	4.00	33.20
23	5.00	5.00	2.00	4.50	3.20	2.70	2.70	3.50	28.60
24	5.00	5.00	5.00	4.75	3.00	4.00	3.70	5.00	35.45
24	3.00	5.00	2.00	4.75	3.20	0.00	2.70	5.00	25.65

- Outstanding projects that had 22 or more integrated elements (80% or more), (11 projects).
- Satisfactory projects that had 12 to 21 integrated elements (40% > 80%), (9 projects).
- Unsatisfactory projects that had 11 or less integrated elements (less than 40%), (5 projects).

(Figure 1) illustrates the outstanding project of the final proposed sustainable design projects to the Izmir Municipality to replace a slum residential area in Bayrakli, Izmir, while (Figure 2) presents the satisfactory project, and (Figure 3) shows the unsatisfactory project. The projects were tested using the energy simulation program for energy consumption and CO_2 emission.

FIGURE 1. Organic housing 'grow your health products', by "Ezgi Çam." The permaculture principles were a direct response to the existing residents environmentally, socially, and economically. Courts, gardens, and terraces provided a suffusion of natural light and natural ventilation to internal spaces. The use of local natural materials, rainwater, and PV panels managed to save 25% in energy consumption and 25% in CO_2 emission reduction. The project scored a full 28 points on the sustainability checklist elements.

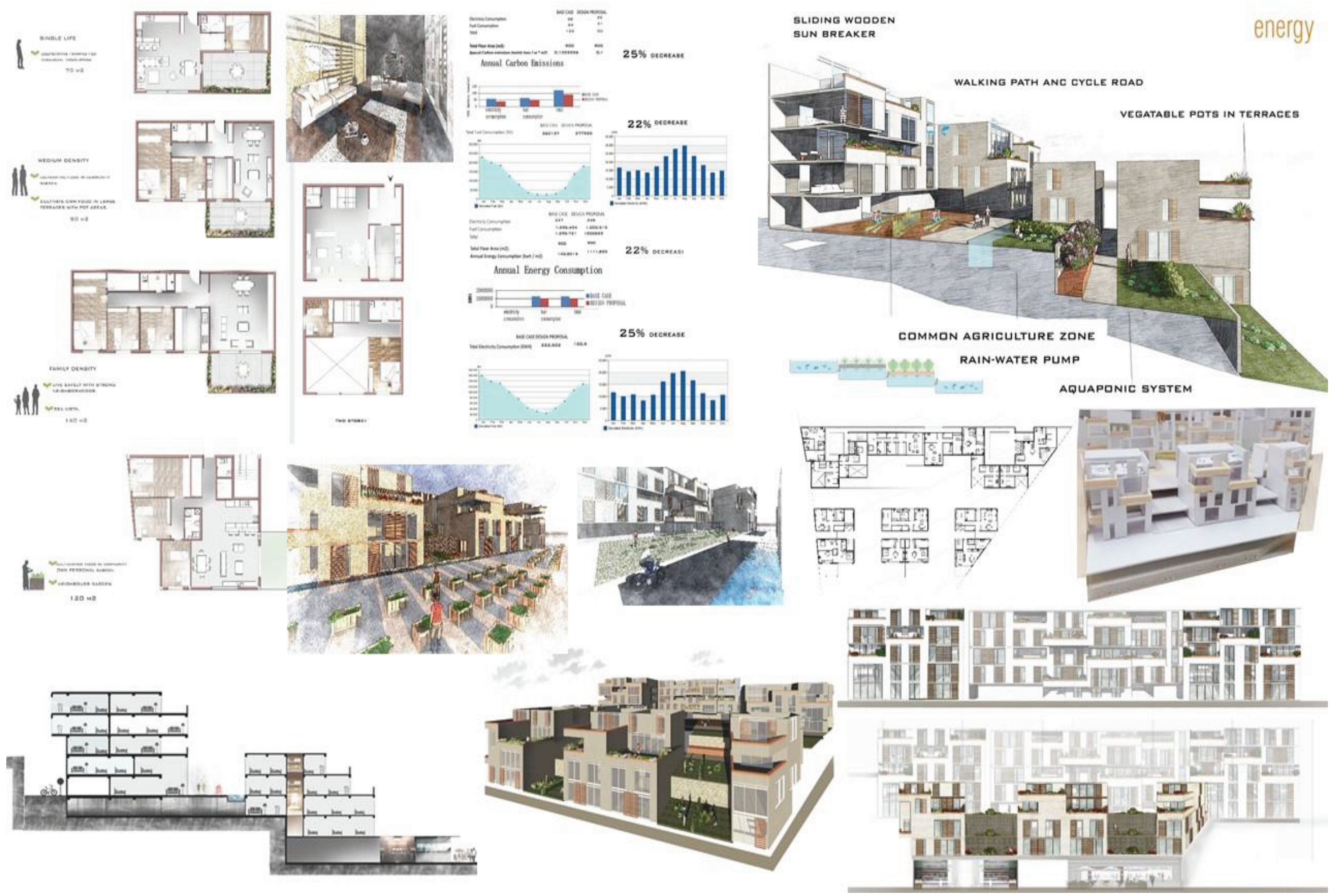


FIGURE 2. The "Alley infill and social sustainability by "Latif Temmuz Babacan." Streets represented great social activities to the residents where they meet, communicate, share, and interact daily. Natural light and natural ventilation were used as well as PV panels, rainwater, sustainable materials, and shading elements to save energy consumption by 22% and 19% CO_2 emission reduction. The project included 21 sustainable design elements of a total of 28 elements.

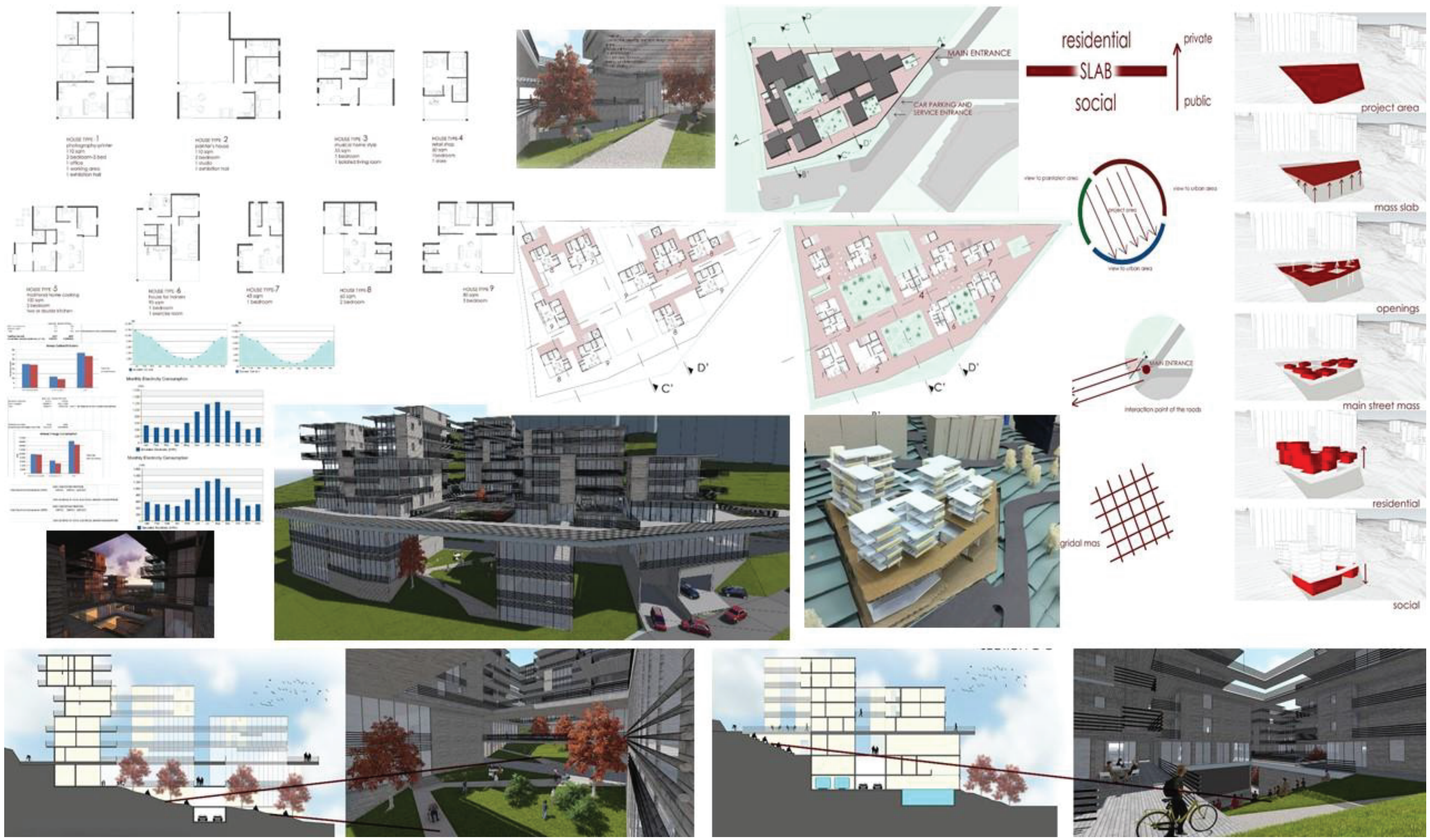


FIGURE 3. The project proposed affordable housing. The project received 8 points of the 28 sustainable design elements. The project failed to use local natural materials and sustainable materials; it has a serious problem of natural ventilation and natural light as well as it had no consideration for using rainwater and sun energy. The project did not provide the correct energy simulation test.

TABLE 3. The number of sustainability elements integrated into each project and grading system of sustainability elements, energy simulation, and daylight tests.

Main Elements / points	Energy (10 Points)									Materials (4 Points)			Water (4 Points)			Health (4 Points)				Social Elements (8 Points)					Economic Elements (5 Points)				Total Elements 28	Total 35 Points	Energy Simulation Tests (15 Points)					Light Simulation Test (Optional)			Total Evaluation 50 Points
Points distribution	8 Elements or more (10) 7 Elements (8) 5 to 6 Elements (6) 3 to 4 Elements (4) 1 to 2 Elements (2) None (0)									3 Elements (4) 2 Elements (3) One element (2) None (0)			3 Elements (4) 2 Elements (3) One element (2) None (0)			4 Elements (4) 2 to 3 Elements (3) One element (2) None (0)				5 Elements (8) 4 Elements (6) 3 Element (5) 2 Elements (4) 1 Element (2) None (0)					4 Elements (5) 3 Elements (4) 2 Elements (3) 1 Element (2) None (0)						(5 Points)	(5 Points)	(8 Points)	(10 Points)		(NO)	(Good)	(Excellent)	
Elements	Reducing the energy used for lighting		Reducing the energy used for ventilation		Reducing energy used for heating and cooling			Use of renewable energy sources																															
Students No.	80% of spaces benefits from natural light	Sky-gardens, skylights, atriums, light shelves	Adjustable windows, air-holes	Natural ventilation by channels (wind catcher)	Reduce heating loads (high insulation glass system (low-e glass), double-wall application, double skin	Reduce cooling loads (sunshades, movable blinds between glass layers, etc.)	Passive recovery to reduce heating and cooling loads (thermal mass, etc.)	Low emission but non-renewable energy sources	Renewable energy sources like sun, and wind	Flexible design of interior space and interior furniture	Use of eco-friendly material and equipment	Reducing waste	Recollection and reuse of water; grey water and ra water	The use of rain water in interior and exterior spac to reduce the cooling load during summer	The use of water in landscape to enhance the natural light in the building	Natural light and fresh air for working area	Indoor glare effect control by using façade's solar shading	Eco friendly transportation to the site (bicycles, electric cars, etc.)	Selection of non-harmful materials	Enhance awareness of available alternative options in local soci structures influencing human behavior to change through collective, democratic, and sustainable ways	Design for cooperation and sustainability	Design for combating the alenation and solation that many experience today	Design for a sense of individual and collective identity	Design for an ecologically oriented society with a belief that the society alone can remove the root cause of the current ecologic crisis	Increase in the use of local available materials in construction instead of expensive imported materials	Change negative perception of low-cost housing as UGLY, NON DURABLE, LOW QUALITY, AND ONLY FOR LOW-INCOME FAMILIES by using cost-effective building technologies and materials	Decrease energy consumption	Allow self-build			Base case result	Modified case with selected materials and shading elements, Reduction of less than 10% in Energy and CO_2 emission	Modified case with selected materials and shading elements, Reduction of 10% to 20% in Energy and CO_2 emission	Modified case with selected materials and shading elements, Reduction of more than 20% in Energy and CO_2 emission	Total 15 Points	No test	less than 60% of the unit has 300 Lux	More than 60% of the unit has 300 Lux	The Integration of Sustainaplity in The Design
1	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X			X	X	25	31	5		8		13	X			44
2	X	X			X			X	X	X			X			X	X	X			X				X		X		13	18	5	5			10		X		28
3	X								X	X				X		X		X			X						X		8	16	5				5	X			21
4	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		26	34	5		8		13			X	47
5	X		X		X		X		X	X				X		X					X						X		10	18	5	5			10	X			28
6	X	X	X			X			X	X	X			X		X	X	X			X	X				X	X	X	16	18	5	5			10	X			28
7	X	X	X	X	X	X	X	X	X	X	X		X	X		X	X	X	X				X		X		X		20	25	5			10	15	X			40
8	X	X	X	X	X	X			X	X				X	X	X	X			X	X								14	24	5	5			10		X		34
9	X	X	X		X		X	X	X	X	X	X	X	X		X	X	X	X		X	X	X		X	X	X		22	28	5			10	15			X	43
10	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	28	35	5			10	15			X	50
11	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		27	34	5			10	15			X	49
12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	28	35	5			10	15			X	50
13	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X		X	X	X	X	26	32	5			10	15			X	47
14	X		X	X					X	X	X			X		X	X	X		X	X	X	X				X		15	20	5		8		13	X			33
15	X	X	X	X	X	X		X	X	X	X	X	X	X		X	X	X	X		X	X	X		X	X	X		23	30	5			10	15			X	45
16		X	X						X	X				X			X				X			X	X		X		10	17	5			10	15	X			32
17	X	X	X	X	X				X	X	X	X		X	X	X	X	X	X	X	X	X	X		X		X		21	26	5			10	15	X			41
18		X	X		X				X					X		X				X	X	X	X						10	18	5				5	X			23
19	X	X			X				X							X	X				X		X				X		9	13	5		8		13	X			26
20	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X			X			X	X	X		22	27	5			10	15	X			42
21	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	28	35	5			10	15			X	50
22	X	X	X	X		X		X	X	X	X					X	X	X	X			X			X		X		16	20	5			10	15			X	35
23	X	X			X	X		X	X		X	X	X			X	X	X							X		X		14	17	5			10	15	X			32
24	X	X	X	X	X	X	X	X	X	X	X	X	X			X	X	X	X	X	X	X					X	X	22	28	5			10	15			X	43
25	X	X	X	X	X	X			X				X			X	X			X	X							X	13	21	5	5			10	X			31
The use of each element in 25 projects	23	22	21	15	20	16	12	15	25	21	17	13	15	18	8	24	22	19	14	13	21	16	14	7	15	10	22	8	The Avarage element number used in the SADS 18,64										37,68

EVALUATION AND ASSESSMENT

The SADS instructors evaluated the students' works. It consisted of two parts: the design process work throughout the semester, and the final product of the design project, which included the degree to which the three aspects of sustainability principles were integrated into the final design. Finally, students were given the opportunity to assess the SADS pedagogy and instructors' teaching methods as well as their own SADS experience with the course.

The Instructors' Evaluation

The sustainability principles checklist was revised and expanded to include the three aspects of sustainability (environmental, economic, and social) (Mohamed and Elias-Ozkan 2018). The checklist elements were demonstrated to the students throughout lectures, workshops, technical trips, and case studies presentations (Table 2). Sustainability checklist elements, Revit energy simulation test, and natural light simulation test (optional) results were counted for 50 points; the distribution of these points is shown in (Table 3). The grade weight illustrated the workload, the time consumed, and integration quality to respond to each student effort during one semester period.

The measuring system was applied to each project. Each project was given the number of elements included in it, while (Table 3) presented the checklist-collected data. The average number of sustainable design elements used over the projects was 18.64 of 28 elements in total. In (Figure 4) presents each sustainable design element integration times in all the students' projects. The average use of each element was 16.64 in 25 projects. The light simulation test was an optional work recommended to the students who had previously taken the elective course of Natural Light in Architecture design. These students were requested to test some of the units' natural light quality--whether or not 60% of the unit total space has at least 300 Lux. Instructors graded the final submission of the project as shown in (Table 4) as well as the final semester's grades, which is presented in (Table 5).

Data Analysis

Afterward, the data collected from various grade system were analyzed to assess the success of the final modification of the SADS pedagogy and teaching method. The new grade system of energy simulation is illustrated in (Figure 5) and the percentage of the energy-saving and CO_2 emission reduction achieved by the students.

While the daylight test was optional work, twelve students managed to achieve it and ten of them succeed to provide 300 Lux to more than 60% of the apartment unit space (Figure 6).

The instructor's evaluation showed a positive correlation trend between the numbers of sustainable design elements and SADS final grades (Figure 7). Besides, there was a positive trend between design process grades (representing the final modified SADS pedagogy structure) and final project grade of the students as shown in (Figure 8). The same positive correlation trend between the total grades of sustainable checklist elements and energy simulation test of each project and the final SADS grade is shown in (Figure 9).

The Students' Assessment

Students' assessment used three tools that assessed the SADS pedagogy, structure and instructors' teaching methods of experimental research. These tools were the questionnaire forms, the SADS open colloquium, and the Izmir Institute of Technology's online class evaluation.

FIGURE 4. The times use of each sustainable design element in the 25 projects.

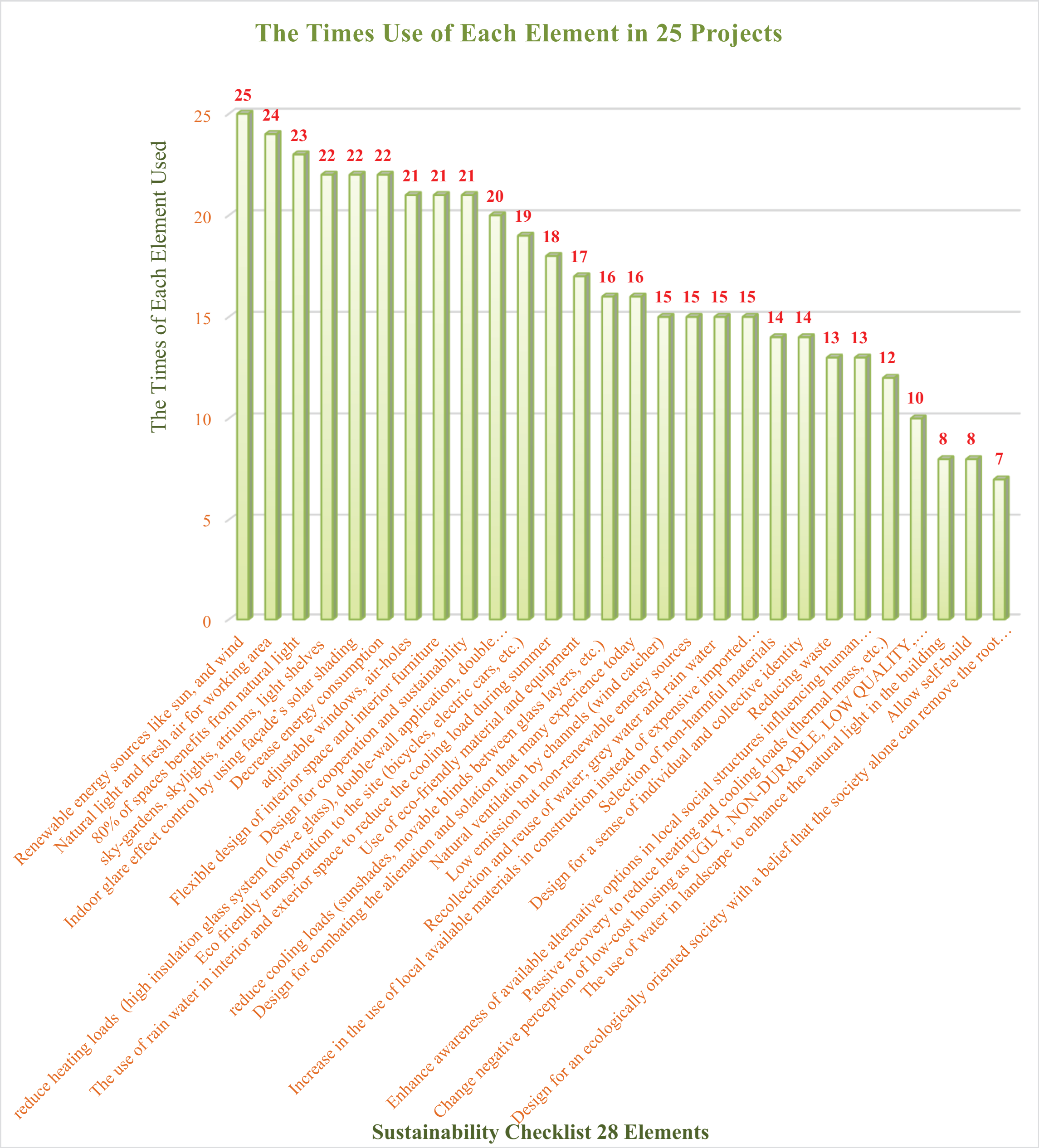


TABLE 4. Third experimental SADS's final project grades.

Students No	Energy (10 pts)	Material (4 Pts)	Water (4 Pts)	Health (4 Pts)	Social Elements (8 Pts)	Economic Elements (5 Pts)	Simulation Bas case (5 Pts)	Simulation modified case (10 Pts)	Total Sus. Checklist & Simulation (50 Pts)	Design Evaluation (50 Pts)	Final Jury Total (100 Pts)
1	10	3	3	4	8	3	5	5	44	47	91
2	6	2	2	3	2	3	5	5	28	44	72
3	2	3	2	3	4	2	5	0	21	39	60
4	10	4	4	4	8	4	5	8	47	41	88
5	6	2	2	2	4	2	5	5	28	42	70
6	4	3	2	3	4	2	5	5	28	28	56
7	10	3	3	4	2	3	5	10	40	43	85
8	8	3	3	3	4	3	5	5	34	44	78
9	8	4	3	4	5	4	5	10	43	40	83
10	10	4	4	4	8	5	5	10	50	46	96
11	10	4	4	4	8	5	5	10	49	47	96
12	10	4	4	4	8	5	5	10	50	46	96
13	10	4	3	4	6	5	5	10	47	45	92
14	5	3	2	3	6	2	5	8	33	40	73
15	10	4	3	4	5	4	5	10	45	48	93
16	4	2	2	2	4	3	5	10	32	38	70
17	6	4	3	4	6	3	5	10	41	39	80
18	4	2	2	2	6	2	5	0	23	39	62
19	4	0	0	3	4	2	5	8	26	38	64
20	10	4	3	4	2	4	5	10	42	44	86
21	10	4	4	4	8	5	5	10	50	45	95
22	8	3	0	4	2	3	5	10	35	39	74
23	6	3	2	3	0	3	5	10	32	34	66
24	10	4	2	4	5	3	5	10	43	47	90
25	8	2	2	3	4	2	5	5	31	43	74

TABLE 5. Third experimental SADS's student's final grades.

Students No.	Design Process Grades (40)	Final Jury (60)	Final Grade (100)	Letter Grades
1	29.80	54.60	84.40	BA
2	31.10	43.20	74.30	CB
3	23.70	36.00	59.70	DD
4	32.60	52.80	85.40	BA
5	30.30	42.00	72.30	CC
6	25.70	33.60	59.30	DD
7	34.10	51.00	85.10	BA
8	33.00	46.80	79.90	BB
9	32.85	49.80	82.65	BB
10	35.60	57.60	93.20	AA
11	35.35	57.60	92.95	AA
12	34.25	57.60	91.85	AA
13	36.35	55.20	91.55	AA
14	26.80	43.80	70.60	CC
15	34.25	55.80	90.05	AA
16	28.25	42.00	70.25	CC
17	32.80	48.00	80.80	BB
18	27.65	37.20	64.85	DC
19	27.60	38.40	66.00	DC
20	33.40	51.60	85.00	BA
21	34.15	57.00	9.15	AA
22	33.20	44.40	77.60	CB
23	28.60	39.60	68.20	DC
24	35.45	54.00	89.45	AA
25	25.65	44.40	70.05	CC

FIGURE 5. Energy saving and CO_2 emission reduction percentage achieved in students' projects.

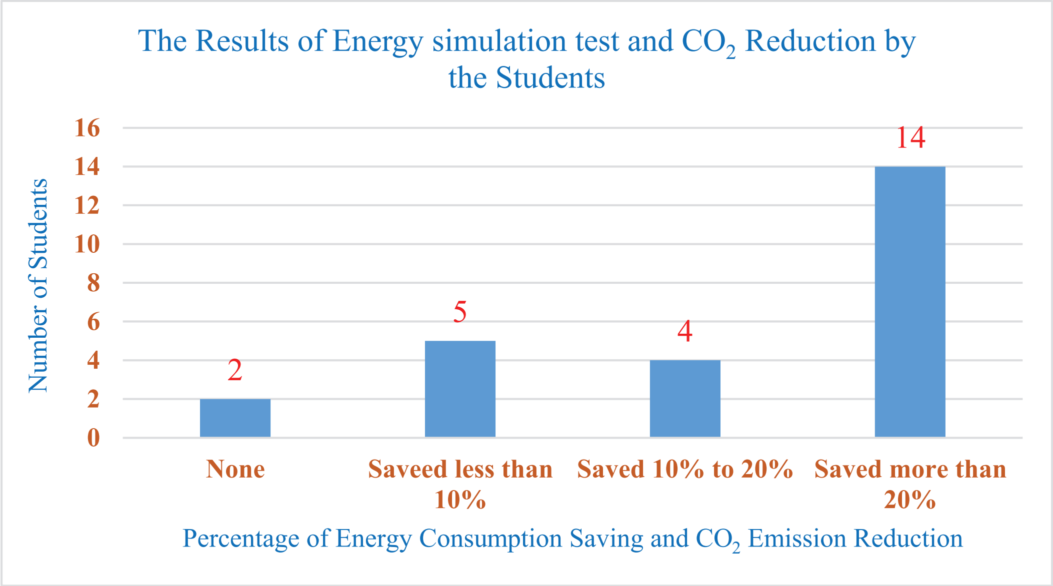


FIGURE 6. Daylight simulation test (Optional test).

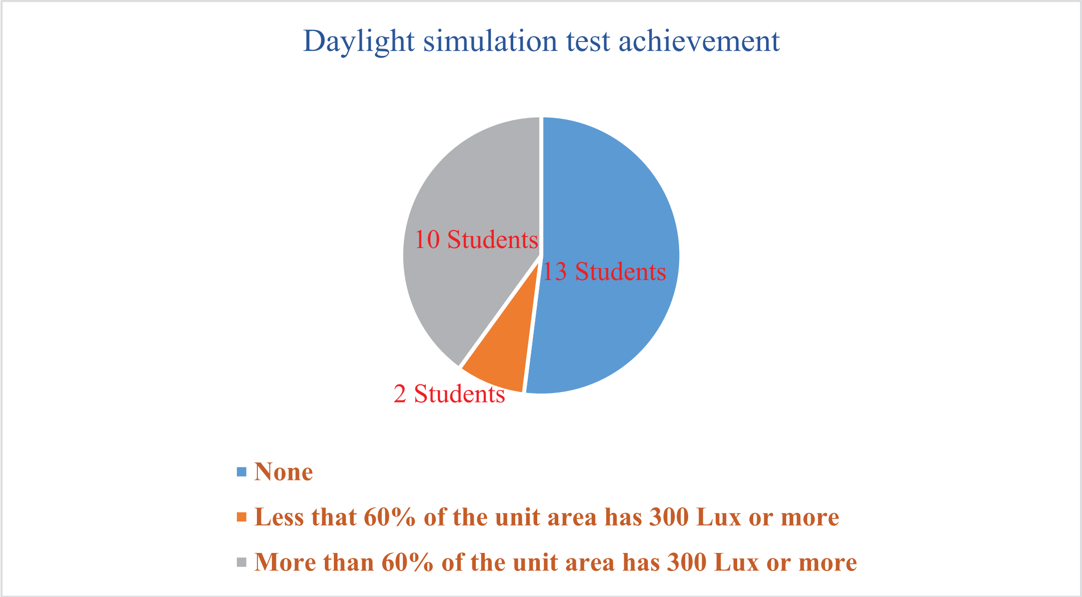


FIGURE 7. The correlation between the number of sustainable design elements each student used in his/her project and the SADS final grade.

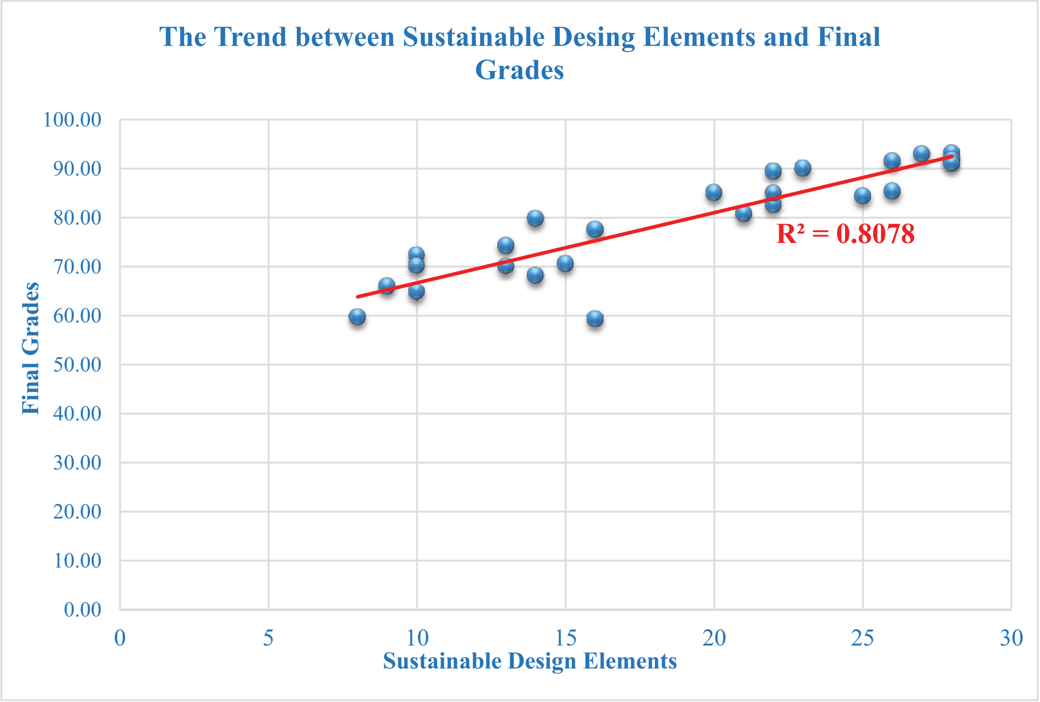


FIGURE 8. Positive trend result between students' design process grades and SADS final grades.

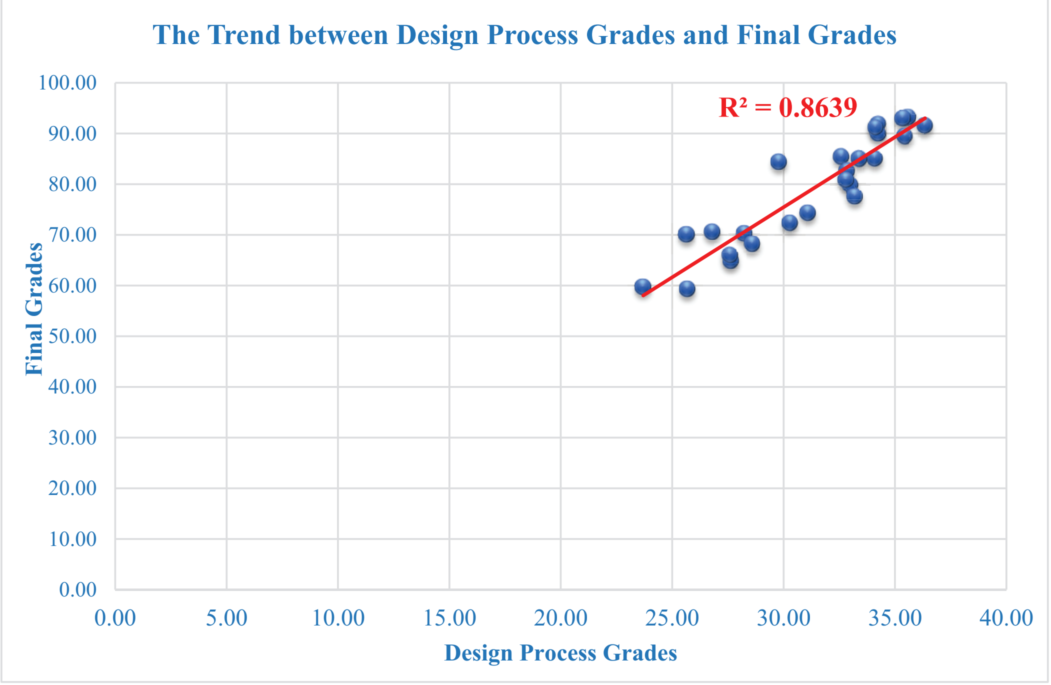
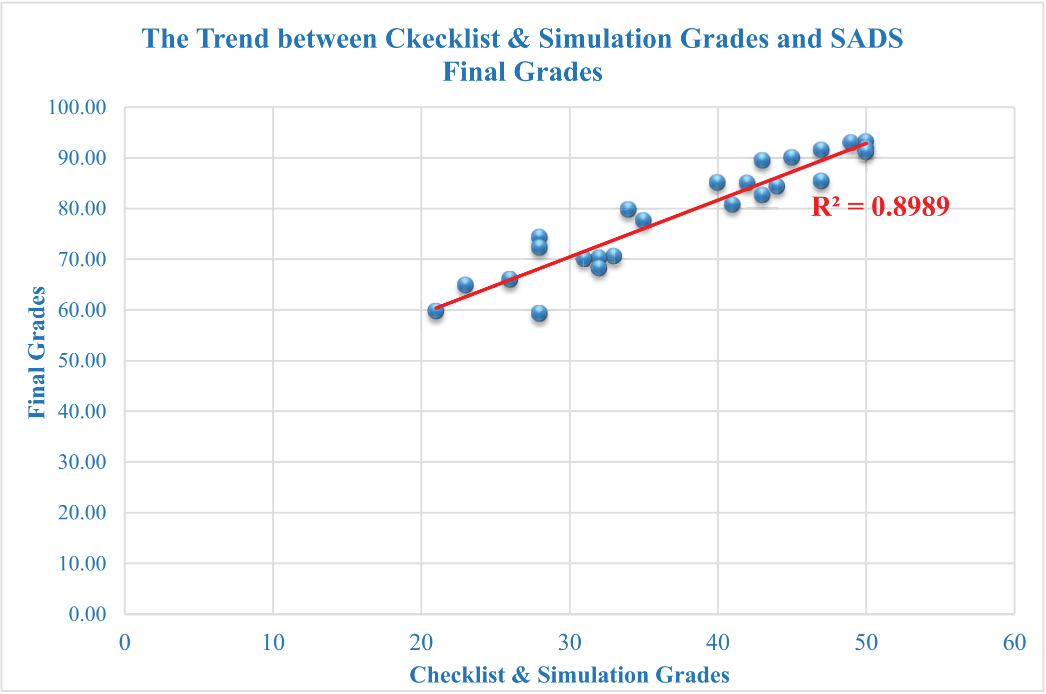


FIGURE 9. The correlation between the total grades of sustainable checklist elements and energy simulation test of the students and the SADS final grades.



The SADS instructors e-mailed the questionnaire survey form to the students after the SADS final grades were posted. Students handed out the forms at the open colloquium's day. The form had nine questions regarding sustainable design issues, studio structure and format, and jury style format as well as students' comments about studio aspects. The form showed that 74% of the students did not know sustainable design before attending SADS, while 96% of the students confirmed that they will practice sustainable design in their professional life as well as being their preference for graduate education.

Fifteen students considered the environmental aspect while fourteen students considered the social issue and twelve students considered the economic part of sustainability. Since the SADS had 25 students, that means some students considered two or three sustainability aspects in their projects as is shown in (Figure 10).

In assessing the SADS pedagogy elements, (Figure 11) illustrated that the technical trip and case studies scored the highest points in benefitting the students while the use of the physical model scored the least points. The natural light and the natural ventilation scored higher points among the SADS principles design elements while eco-friendly transportation scored the lowest point within the students' consideration (Figure 12).

In general, there was a positive and appreciative mood towered the materials they have learned. The vast majority of the students said that they found the studio pedagogy efficient to learn the principles of sustainable design. Most of the students found the timetable module of the SADS (4+4+4+2) hard but it provided discipline to achieve the design work along the semester. Many students appreciated the visiting instructors' lectures and their workshops. Also, they were pleased to have the Izmir city municipality representatives and their University President in their final jury, which brought reality to the work of the design achieved. Individuals

FIGURE 10. Sustainability aspects considered by the students in their design.

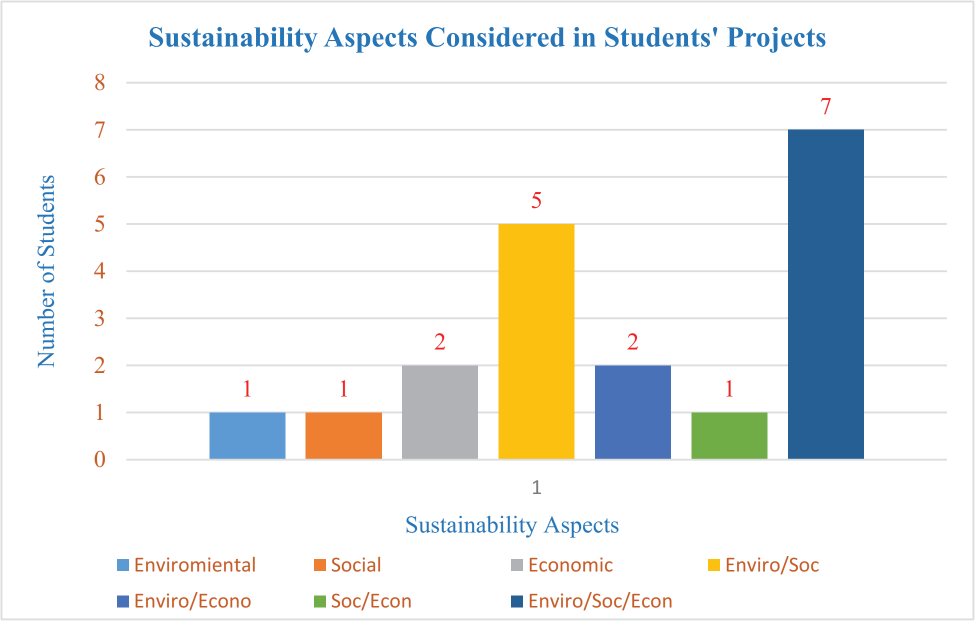


FIGURE 11. The scored points average of SADS pedagogy structure elements.

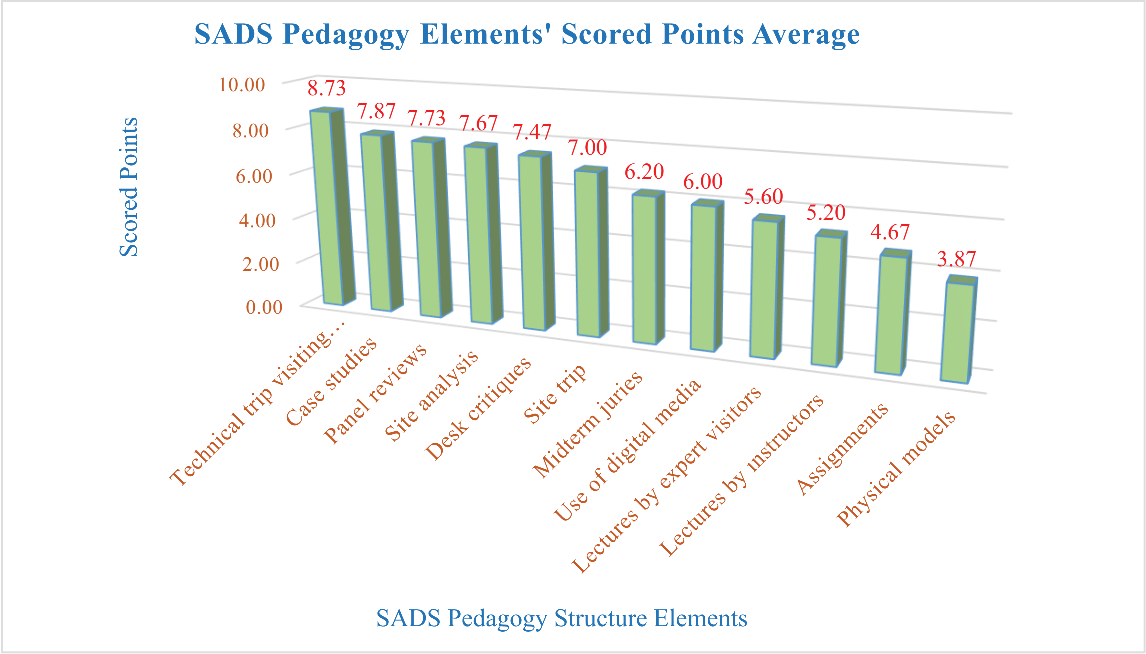
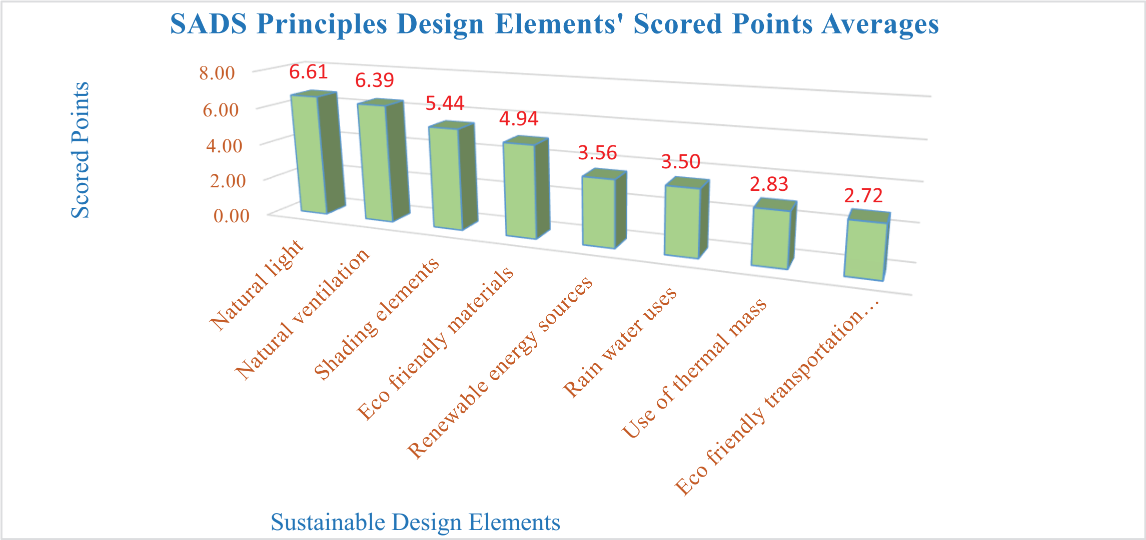


FIGURE 12. The scored points average of SADS principles design elements.



complained that the motivation was not enough and it was hard. Another student said, "It was hard, I learned many things, in the end, it was joyful."

DISCUSSION

The aim of the architecture department at IYTE is to produce architects competent in the design and execution of sustainable buildings. Meanwhile, the current conventional design studio pedagogy does not support this aim. The SADS was an attempt at integrating sustainability principles, and the technical courses knowledge into the architecture design studio project. That required the creation of a new studio pedagogy followed by an innovative teaching method that was supported by a firm timetable of studio activities and tasks. The design process was the key point of implementing the integration of sustainability into the design studio. Defined tasks were given to students using the creative teaching method and with a designed timetable to integrate sustainable design principles into the architecture project. The main task was designing a sustainable architecture project. However, there were minor tasks throughout the design process, which were employed to achieve the main task. These were site analysis, case studies presentations, analyzing technical trip's buildings, juries requirements, charrette studio assignments, energy and daylight simulation, study models, and construction details drawings. Those tasks were modified from time-to-time according to accommodate the students' learning level as well as instructors' observations.

CONCLUSIONS & RECOMMENDATIONS

The class average of the use of sustainable design elements in each project was 18.64 elements of a total of 28 elements (Table 3). Each sustainable design element's average use in the total of 25 projects was 16.65 (Figure 4). Although there were no grades assigned for the daylight simulation test, more than half of the students managed to achieve it (Figure 6). The energy simulation test result showed that 56% of the students managed to design a project that reduced more than 20% in energy consumption and CO_2 emission reduction (Figure 5). There was a positive correlation between the number of sustainable elements each student used in his/her project and the final SADS grade (Figure 7). There was a positive parallel trend result between students' design process grades and final SADS grade (Figure 8). There was a correlation between the total grades of sustainable checklist elements and energy simulation test (50 points), and final SADS grades (Figure 9).

Considering the three sustainability aspects (environmental, economic, and social), the assessment showed that 37% included three aspects, and 42% included two aspects while 21% had one aspect in their project, which was a positive level of integration (Figure 10). The technical trip and case studies were at the top of the students' choice list of SADS pedagogy elements (Figure 11). The SADS's students (Figure 13) had no experience with housing projects from previous studios, which might explain some of their comments regarding the high workload. The natural daylight and natural ventilation had the top score among students' choice for SADS design principles elements where eco-friendly transportation scored the least points (Figure 12).

It is recommended in the future that the project size (meter square) should be reduced to give students a better chance to focus on sustainable design issues. Also, Revit and DesignBuilder software programs courses should be offered in an earlier semester. The technical trip should be more than one trip per semester. Study models should be made easier in terms of materials and techniques. Continually, simulation should be used for the evaluation of natural daylight quality of the space.

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FIGURE 13. SADS's students—class of AR 302 spring 2016 on their technical trip.

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