

RECYCLED- BOTTLE ARCH AS A PROTOTYPE TO PRACTICE SUSTAINABILITY THROUGH PBL

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ABSTRACT

This paper is a brief description of attempts of high school students during their experience to gain knowledge about environmental sustainability through an architectural project in Iran. Students are concerned with the waste materials produced by households and tried to draw the other students' attention to this issue with their project. Waste milk bottles were used as the primary material of their final project. The result of the project is a 150-centimeter-high and 160-centimeter-span arch, which had been constructed with the use of used milk bottles.

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INTRODUCTION

The importance of nature and the environment for human beings cannot be emphasised enough. In the primitive era, nature had a considerable effect on the lives of people and shaped their activities. Our ancestors had to manage all of their daily chores in accordance with their surrounding nature. Thunderstorms, winds, earthquakes and other types of natural forces had direct influence on their daily lives. Over time, by gaining knowledge and promoting humans' intellectual ability, they could change this unilateral relation to a bilateral one. It means human beings, by using their skills, could overcome the difficulties imposed by their natural surroundings. Gradually the humans found ways to overcome the challenges presented by nature whereby some had exploited the natural environment for their own selfish gains.

As time elapsed the rate of this trend changed into a concern for environmentalists. In recent decades, there has been a surge in exploitation of nature that has become a widespread concern for almost all of the nations around the world. This had resulted in devising numerous solutions to overcome this global problem. "Sustainability" has emerged regarding the mentioned concern.

In this study, the focus is on describing the process of educating high school students with the concept of sustainability through the design and construction of an architectural form with the use of household wastes, precisely the same process in project-based learning (PBL). The students who were concerned about the amount and adverse effects of the waste produced of households tried to share this concern with others via their project. This project was conducted at the Architecture Research Club in Kherad educational complex in Tehran, Iran.

The multidisciplinary essence of architecture made this process possible as it is prone to have a wide range of usage: from a well-known major in university to design and to construct buildings to form the basis of some extracurricular activities whereby the educators can transform the knowledge.

LITERATURE REVIEW

Sustainability

“Sustainability” as a recently-emerged term is related to the methods of utilizing a resource so that the resource is not destroyed or damaged permanently. Sustainability results in a deep concern about the impact of human activity on the environment (Bennetts, Radford & Williamson. 2003). “Environmental sustainability prohibits damaging effects on the environment by applying efficiently of renewable sources, natural sources and preserving the water, soil, and air from pollution” (Ghaderi. 2016). Very soon, the mentioned concept found its place in all sectors of developed societies, and consequently in developing countries, as a pervasive trend which needed special attention. One of the main areas of these societies, which has been affected, is the education system. The footprint of this trend has been apparent in education systems of the concerned countries.

Learning through PBL

The education systems can impressively influence the whole society by gradually establishing ethics and rules in the body of society, especially students. This process not only can include university students but also all students studying in an education system. Designing and developing courses, curricula, degrees, and programs prove the ability of educational system to be inclusive. Thus the role of an educational policy in permeating an ethic or culture in society is undeniable.

Two primitive methods of education consist of lecture-based learning and problem-based learning (PBL). In the lecture-based instruction (LBI), the teacher presents the content of the lessons and the activities which can deepen students’ learning. The knowledge acquisition of students is measured through the test at the end of the experience or the semester.

In contrast, Project-based learning (PBL) is an approach in which students start their learning process with a project or problem. This method encourages students to ask questions, try to find answers or solutions, and reform their process by reviewing the course. It means that they are responsible for their own knowledge acquisition (Ward & Lee. 2004). In

this process teachers play the role of facilitators. Students ask the questions. In addition, during the course of finding solutions, teachers will assist the students to guide as well as help them. The answer will be derived through research, investigation, testing and experiencing while teachers superintend the process of answering (Bell. 2010). With this approach students play a pivotal role by asking, discussing, defending their ideas, making some comments and sharing new ideas instead of passively listening to their teachers. Each student in this approach has an individual influence and plays his role in the team (Tasci. 2015).

The Education System in Iran and the Approach of the Architecture Club at Kherad High School

The education system in Iran revolves around the lecture-based method. It consists of students as passive listeners and teachers as the only speakers (Safari & Pourhashemi. 2012) who presented the lectures. Teachers teach students lessons. At the end of each semester students have to pass an exam to prove their expertise in the guided example. Despite the pervasive and common trend in Iran, the Architecture Club at Kherad high school chose a different method to show sustainability to its students.

An early acquaintance of students with the concept of sustainability makes them sensitive about this issue in their lives. Accordingly, some extra-curricular activities have been established in private educational complexes in Iran like Manzoumeh Kherad Educational Complex to make the students familiar with the mentioned trend. The Architecture Club, besides several clubs related to the other fields of knowledge, has been established to meet the needs of students to learn about sustainability, nature and the future of their environment through architectural projects.

The Architecture Club in this educational complex tries to make the students aware of the impact of human behaviour and their lifestyles on nature in a way completely different from the current teaching methods in Iran. The Architecture Club applies a profoundly different approach namely PBL, to teach the concept of sustainability to high school students.

Waste material as a Global Concern

Environmental pollution and waste materials stem from individual lifestyle and activities. Cities around the world are producing about 1.3 billion tonnes of municipal solid waste each year, and this amount will increase to 2.2 million tonnes by 2025 (Hebel, Wisniewska & Heisel. 2014). The mentioned figure for the near future is bewildering and frightening.

Based on a research which was carried out in 2013 the amount of solid waste production in Iran was about 0.89 kg per capita per day whereby 75% of the total amount include organic wastes, 5% paper, and cupboard and 6% plastics (Hatami, Memarian fard & Sabour. 2016).

When a product is generated from natural resources and material, its life span is limited to the duration of its usage. For example, a life span of a bottle of water starts from its production until someone drinks it up, and then it is considered as trash, which is the end of its lifespan.

There are so many concerns about waste material in the landfill and the whole situation of collecting waste. Mixed waste, toxic materials and the combination of all contaminated substances without any protection system can cause significant problems. In some cases the garbage transfers from a country to another country. For example, the United States of America pays for the transferring of its produced waste to China. Another example is Ghana where people happily accept e-waste from other parts of the world because of profit. Moreover, people around the dumpsite can burn the e-waste to extract some precious metal like copper and aluminium. Air pollution is the inevitable result and the minimum adverse side-effect of the abovementioned process.

The vast usage of plastic bags around the world can cause significant problems and adverse effects. Oil is the raw material to produce this product and the same quantity of fuel to provide its required production energy for the manufacturer. As a result of this process, about one kilogram of carbon dioxide (CO₂) is released to produce five average-size plastic bags. It should be noted that about half of this amount could be eliminated or saved if the countries start to recycle plastic waste, the act which can restrain emitting more CO₂ and toxic fumes to the atmosphere. However,

what usually happens instead is the practice of dumping trash in landfills, burning the wastes or throwing them away indiscriminately. The figures for other industries are more concerning. Moreover, steel and paper production both need more considerable energy to produce from raw materials than recycling from waste materials (Hebel, Wisniewska & Heisel. 2014).

Waste Materials and Architecture

Architects need materials to make virtual designs into real buildings. They can use either raw material or the waste resulted from other activities. Numerous prototypes, researches and outputs have been carried out all over the world in order to use the waste material in construction which include: insulation infill, insulating panel, insulating bricks and blocks, construction panels, waterproofing panels and finishing tiles (figure 1) (Hebel, Wisniewska & Heisel. 2014).



Figure 1: United Bottle, Water Bricks, Construction Bricks, UPM ProFi, Construction Profiles
(Source: Hebel et al, 2014)

Construction employing waste is known as creative work. One of the innovative prototypes with recycled bottles is Polli-Bricks, which is done by the Miniwize group in the United States. Its thermal and sound insulating feature, in addition to its resistance, makes it a unique exploit architecture (Minimize group, 2009).

Another interesting prototype of this kind is the WOBO summer house, which is constructed with the use of discarded bottles. The main issue about both current projects is their principal constructing component which was designed to be used as constructing material.



Figure 2: The Logic of Making the Prototype
(Source: inhabitat.com)



Figure 3: Logic of Interlocking the Components
(Source: Heineken, 1964)

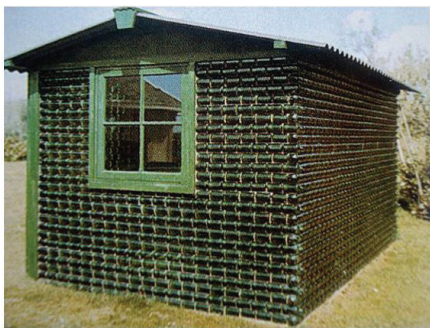


Figure 4: The Final Product
(Source: Besana & Ferrari. 2019)

Apart from showing the creativity of designers, the waste material can economize construction for people. In some projects especially in slums and impoverished areas around the world, waste bottles have been used to construct permanent homes for destitute people (figure 5, 6) (Goud. 2014 and Saxena & Singh. 2013).



Figure 5: Bottle Bricks as Bricks in Construction
(Source: thehomestead.guru)



Figure 6: Bottle inCconstruction in Guatemala
(Source: tammyblomsterberg.com)

Bottle bricks refer to PET bottles that are filled with sand or other inorganic trashes. It is a low cost, environmentally friendly, and sustainable method in indigence areas around the world that uses the waste material (PET bottles) and the material available in their habitat (sand or other

inorganic trashes). It is a standard method in Nigeria, India, South and Central America based on Goud's research. In this method bottle bricks outlast the cement more than 300 years, which binds the bottles to shape the walls. Durability and strength of the mentioned material are correctly estimated to build a 3-storey building. This method in comparison with the masonry method which is common in the mentioned areas is considerably cheaper, faster, and less energy-consuming (Goud. 2014).

METHODOLOGY

Planning the Research

Manzoumeh Kherad is a private educational complex in Tehran that holds several 6-month workshops, on an annual basis, for different clubs of students from the 7th, 8th, 9th, and 10th grade to help them put their theoretical knowledge into practice and make them familiar with ongoing issues of the globe. Teachers of each club try to plan experiments for students to come up with real results for their experiments. The other opportunity that is given to each club is recognizing personal talent and enhancing different skills, improving self-confidence, and presenting the best award of the finale of the Clubs at the end of the educational year.

Last year, 2018, the focus of the Architecture Club was the concept of sustainability for students of 7th grade (13-year-old girls). After a brief presentation about the importance of nature and the preferred topics of the Club by teachers, students arranged their team based on their common interests and started their project by posing some questions. Their questions had some features: the question should be a daily life challenge, it should consider a human life concern, and it should have the potential to be solved by employing an architectural project.

Three students in the 7th grade who were eager to learn about the concept of sustainability joined together and concentrated on their home. They aimed to discover if they can find some creative solutions to make their homes more sustainable. Solid waste material generated in the kitchen drew their attention and encouraged them to search and know more about it. Thus, the main questions were posed:

1. What is the life cycle of the solid waste material (SWM)?
2. How can the life span of SWM be prolonged?
3. How can SWM be used as a construction material for architectural projects?
4. Is there any other application for the final project? Where and how?

They referred to websites and online libraries for data collection and to familiarise themselves with the concept of the project. The data presented in the literature review section made them confident with the focus on solid waste material generated by households as the base of their research.

The process of students' effort and practice during the project is summarized as follows:

1. Phase 1: problem/ question finding
2. Phase 2: gain knowledge related to the issue
3. Phase 3: choose the material, experience several modules, and opt the architectural form
4. Phase 4: provide details and create the final form

Material Selection

Based on the mentioned process above, plastic bottles that were available and considerable in multitude in households were chosen as the solid waste material to construct their architectural forms.

The process of finding a proper architectural form was an exciting challenge for students. They had seen several bottles which were different in shapes and tried to attach them by elastic straps and construct modules (figure 7, 8, 9 and 10). Some modules were accepted, but some did not have the potential to be used as a construction module.



Figure 7: Experience with Water Bottles (250cc volume) and Elastic Strap

Source: Author



Figure 8: Experience with Water Bottles (1litre volume) and Elastic Strap

Source: Author









Figure 9: Experience with Milk Bottles (1litre volume) and Elastic Strap

Source: Author



Figure 10: Experience with Milk Bottles (1litre volume) and Elastic Strap
Source: Author

Table 1: Comparison of Different Types of Waste Bottles

	Type of bottles	picture	Strength in lateral force exposure	Strength in upright force exposure	Expandability	availability	Stability in attachment
1	Bottled water (0.5 liters)		-	-	+	+	-
2	Bottled water (1.5 liters)		-	-	+	+	-
3	Bottled milk (1 liter)		+	+	+	-	+
4	Bottled milk (0.9 liters)		+	+	+	+	+
5	Cocacola bottle (0.5 litre)		+	+	+	-	+
6	Cocacolabottle (1.5 litre)		+	+	+	-	+

Source: Author

According to Table 1, a comparison between the available waste bottles based on certain criteria was carried out. All the bottles other than numbers 1 and 2 showed enough strength in exposure of lateral and vertical forces. Bottles 4 and 5 were omitted because their content included high level of sugar which is not suitable for the health of high school students. Between bottles 3 and 4 both were found to be appropriate based on the abovementioned criteria, while bottle 4 was chosen because of its availability.

Hence, the selected type of bottle was milk bottle from the Damdaran brand, which was available, proper in shape, had potential of expansion, attachment, and possess more stability. Students published an announcement all over the school and asked the other students to help them by delivering their waste milk bottles to the club. Besides, they called the manufacturer company and asked them to take part in the project by providing required waste bottles. Finally, the team could produce about 250 bottles which they needed for the project.

In the next step, students invented a method to produce the based module of their construction. They cut a bottle and joined it to the bottom of another intact bottle as shown in Figure 11. Then this module, doubled-bottle as they denominated, was attached to two entire bottles at each neck by elastic straps, as shown in Figure 12.

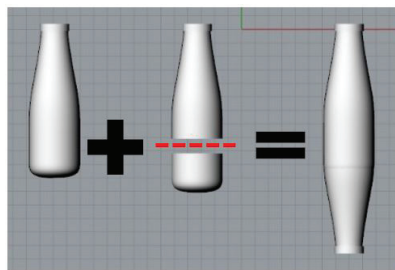


Figure 11: The Logic of Making Doubled-Bottle Module

Source: Author

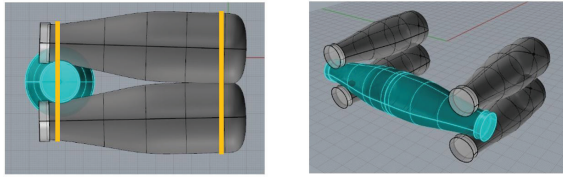


Figure 12: The Logic of Attaching Doubled-Bottle with Intact Bottles by Using Elastic Strap

Source: Author

Stability of the Modules

As the modules were erecting, they showed some instability in length (Figure 15). Therefore, students used plastic straps, which are used to wrap home appliance packages as stiffeners to restrain the movement of modules and prevent sliding on each other (Figures 14 and 15) as the elastic straps were not able to endure the weight of the structure the plastic straps joint with rivet (figure 16). The result from these attempts was a 110-centimeter-high arch (figure 16). To prevent two bases of the arch from lateral drift, two square-based columns were attached to each end of the arch (figure 17, 18 and 19).



Figure 13: The Method of Attaching Bottles Together

Source: Author



Figure 14: Expansion of the Module
Source: Author



Figure 15: Using Straps as Stiffener
Source: Author

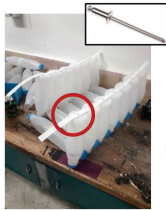


Figure 16: Join the Straps with Rivets
Source: Author



Figure 17: Process of Producing the Columns. (1) Doubled-Bottles Attached by Elastic Straps. (2) Plastic Straps as Stiffeners
Source: Author



Figure 18: Final form Column
Source: Author



Figure 19: Attaching the Arch with the Columns
Source: Author

RESULTS AND DISCUSSIONS

The process experienced in this project is the implementation of PBL to increase students’ knowledge and sensitivity to the concept of sustainability. The mentioned process conducted by three high school students is shown in Figure 20.

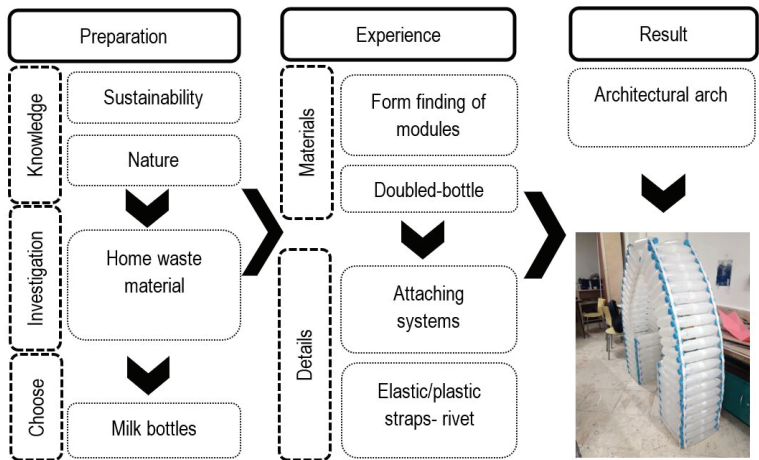


Figure 20: Conceptual Model of the Project
Source: Author

Studying and exploring while being familiar with sustainability, its importance and effects led students to choose a type of waste materials from their home as the primary material of their project. They chose milk bottles as their material of construction. The process of providing the bottles they needed was a good example of collaboration and teamwork.

After procuring the required bottles, form-finding attempts led to the generation of a creative doubled-bottle module, which was the foundation of their final model. The next challenge was the method of attaching the bottles. It was solved by a simple solution, using elastic straps for temporary stability of the structure and using plastic straps and rivet to increase the consistency and integration of the final composition. The permanent challenges faced by the students during the project made the project process-oriented instead of result-oriented, which was utterly different from the conventional teaching

and learning method in Iran. The final form which was an architectural arch is shown in Figure 21.



Figure 21: Final Architectural Form and its Producers

Source: Author

CONCLUSION

Architecture can play an essential role in the process of teaching students. Due to its project-based nature, it has the potential to be used in the process of teaching and learning. In this paper the role of waste materials related to the concept of sustainability in the form of an architectural project has been experienced.

This experience was profoundly fruitful for students, as they mentioned at the finale of the Club. It made them sensitive about the concept of sustainability in their surroundings. Some of them stated that they would make certain changes to their lifestyle which included the following:

1. Considering waste separation in their home
2. Choosing a product with reusable packages to reduce the solid waste materials during shopping
3. Reducing the use of paper cups and dishes
4. Inventing new application for waste material in their home (to create crafting)

Since the registered students in the Architecture Club in the current year 2019, who are eager to challenge topics related to sustainability show a

considerable increase, it seems that the experience of sustainability through carrying out a project was successful.

The architecture Club is going to generalize its method by using other types of solid waste materials in homes, for example, used CDs, DVDs and so on.

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