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Critical Thinking and Collaborative Problem-Solving for Improving Education Performance – Case Study Thermal Retrofit to Ensure Health and Wellbeing of Historic Built Environment in Lebanon

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Abstract

The global ecological crisis is an indispensable issue that needs to be solved. The importance of developing critical thinking and communication skills in teaching-learning methods will help to enhance education performance; as well, the students would become informed participants in environmental decision-making. Lebanon is suffering from multiple ecological problems due to the environmental mismanagement, particularly energy problems. For this reason, training the Lebanese students mainly in architecture schools should to think critically about environmental issues, and using collaborative problem-solving as one of teaching-learning methods and techniques, which will be directly reflected in finding solutions to the problem under investigation. The researcher aims to experiment and apply this method in a history of architecture class at faculty of architecture, to improve the environmental quality of health and wellbeing in historical built environment. This will increase the awareness for conservation aspects of architectural heritage in students, on the one hand. In addition to spread the spirit of teamwork, to facilitate the concept of integrated design process between the different disciplines when practicing professional life, on the other hand. Therefore, the study aims to produce a new methodology for integrating teaching-learning method in architecture, presenting various international attempts of thermal retrofit in historical built environment, guiding the architectural students to follow the same approach of such projects, which will save energy in a country that has a major problem in electricity. The case study is based on a real problem in a realistic situation in Tripoli old Souks at north Lebanon, in which the instructor and the students will analyze and propose some solutions of building thermal retrofit within this historical context, using collaborative problem-solving strategy that could clarifying its reversal extent on the validity of health and wellbeing with the continuity of conserving the architectural heritage.

Keywords

Critical Thinking; Collaborative Problem-Solving; Education Performance; Thermal Retrofit; Historic Built Environment

1. Introduction

The global ecological crisis is an indispensable issue that needs to be solved. In his article Examining Development Education in Testing Times, Fielder (2009) says that people are craving good news in times of global crises, but to have honest good news has become a scarce luxury, especially to someone working in the area of developmental education and global justice. Hence, a developmental education response to the current crisis has to be framed as an educational perspective that accounts for the seriousness of the current economic state. Unfortunately, the crisis has affected people on a subconscious level where people's confidence in the political, social and economic system in which they grew up has been radically put into doubt by reality. This crisis has opened our eyes to reconsidering the ways we do things, live our lives and – as educators – teach, learn and think about the world. Thus, critical thinking skills should be developed in the curricula to help educators and students solve problems because our learners will need not only to anticipate and figure out what the problem is, but also have the skills, confidence, knowledge and interpersonal/management capabilities to be able to deal with problems as they arise. For this reason, teachers' professional and personal concerns are considered crucial factors that will bring about the change (Peacock 2009). Collier believes that "to build a unity of purpose, thinking needs to change, not just within the development agencies but among the wider electorates whose views shape what is possible. Without an informed electorate, politicians will continue to use the bottom billion merely for photo opportunities rather than promoting real transformation" (Collier 2008: xii).

The teaching-learning methods or active learning techniques enhances the students' knowledge and understanding of the course content, thence, developing friendships and networks through active learning course activities could also assist students in establishing a certain identity in the social communities of their universities. Active learning methods are specific educational techniques that are related to the skills of the instructor(s) and the way they deal with the students. Through active learning techniques, students can produce wide variations in quality and educational objectives that can be achieved, such as project-based learning, problem-based learning, research-based learning, problem-solving, simulation-based learning, design-build, etc. (Braxton et al. 2000; Donnelly & Fitzmaurice 2005).

Because our environmental crisis is due to the inability of humans to think about ecological patterns, systems of causation and long-term effects of human actions, ecological literacy should be included in education (Orr 1994), especially in architecture. Fortunately, individuals with ecological awareness have started to prefer nature-friendly products as they gain awareness of an ecological life. Öztürk-Demirbaş (2015) maintains that building one's life on ecological values is only possible through raising awareness about the subject through education. In his article, teaching eco-literacy during a period of uncertainty, Peacock (2009) addresses the difficulty of developing an appropriate eco-literacy curriculum, and suggests that key skills and attitudes are needed, including respect for evidence, understanding risk and predictability in relation to ethics, and communication skills and action competence. The study also contributes to a broader understanding for the practice of thermal retrofit of historic and heritage buildings, in order to improve environmental quality in historical built environment, where the students with the aid of their instructor analyze and propose some solutions of building thermal retrofit within the historical context using collaborative problem-solving strategy. However, more future studies using quantitative methods as tools of measurement, simulation and development to prove the effectiveness of these solutions should be considered.

2. Improving education performance techniques

2.1. Critical thinking and communication skills

The importance of developing critical thinking and communication skills in teaching eco-literacy will help the students become informed participants in environmental decision-making. Thus, the goal is to train students to think critically about environmental issues, and there is a wide variety of critical thinking approaches that can profitably be brought to bear on environmental issues. Six critical skills that underlie critical thinking in the environmental science can be identified, as follows (Yurtoğlu 2018):

1. Healthy skepticism and awareness of political and social biases in oneself and within the environmental science.
2. Familiarity with and willingness to use simple quantitative reasoning to tackle unfamiliar problems.
3. Ability to use simple models to formalize thinking about unfamiliar problems.

4. Effective use of what you already know to tackle new problems, especially an awareness of how just a few basic scientific laws help clarify problems.
5. Understanding of how variability influences what we know and what we can know about the world around us.
6. Ability to think quickly and informally about scientific claims, and especially developing an effective ability to say "that makes sense" or "that sounds implausible" when presented with quantitative estimates.

When students in architecture schools apply these skills, they are not only pinpointing the problem but also finding a solution for the problem, which is considered a target in education. Thus, it is important to think critically and try to find variable solutions for the environmental problems. Having a new generation of critical thinkers will be reflected in a bunch of decisions that are made to protect our environment (Peacock 2009; Yurtoğlu 2018).

There are many practical applications for ecology in critical thinking and communication skills. There has been a high emphasis on literacy in the primary phase in recent years, though in the UK this has tended to focus on reading and writing, to the detriment of listening and speaking. Such skills are crucial in relation to what has been called action competence, i.e. the skills needed to get things done and achieve change (Peacock 2009). This proves that literacy in ecology can be acquired through presenting the material and exposing the students to texts, audios, videos, presentations, etc… and discussing these issues whether in writing or in speaking. This will familiarize the students with the terms that are related to the environment and enrich their knowledge in the area (Yurtoğlu 2018).

The ever-increasing consumption, use of pesticides and egocentric behaviors in people's lives ruin everything natural. To choose the natural and minimize the individual consumption is the essence of ecological life (Yuce 2018). Unfortunately, our world is changing in many ways that threaten the sustainability of life on Earth where human activity is considered as the major corruptor of this planet (Zeunert 2017). Ecologists believe that an ecosystem approach is essential for addressing the environmental issues facing our world today. Not only should the scientific community understand this, but also managers, policy makers, teachers/instructors, and citizens must grasp the concepts of ecosystem function for environmental change. Sadly, there is a gap in society's understanding of ecosystems (Maybin 2006; Zeunert 2017). To see the world from an environmental lens, ecological literacy is needed. Thus, we need to go beyond text books and engage learners in the real world of ecosystems where it will combine research and education to help address threatening concerns facing our society. Ecological literacy highlights the interrelationship between ecology, economy, and society. It places humans as central parts of ecosystems and recognizes the effects of relations between humans and other species. Therefore, it is crucial that our society develops a new understanding and a new awareness of human's relation to his environment (Maybin 2006; Yuce 2018).

2.2. Collaborative problem-solving methods

Collaboration is a working practice whereby individuals work together to a common purpose to achieve business benefit. Collaboration enables individuals to work together to achieve a defined and common business purpose; collaboration concept is "the way a team plays as a whole determines its success. You may have the greatest bunch of individual stars in the world, but if they don't play together, the club won't be worth a dime" (Babe Ruth, Legendary baseball player; 1895-1948). It exists in two forms: Synchronous; where everyone interacts in real time, as in live sessions or online meetings through instant messaging and/or via Skype, and Asynchronous; where the interaction can be time-shifted, as when uploading documents or annotations to shared workspaces (Slimani et al. 2006).

One of the principal differences of the process is that the architect is not simply the form-giver, but an active participant in exploring alternative ideas within a broader team of experts who play active roles earlier in the process, "Everyone is a co-learner in the process" (Bill Reed, SEFC IDP Workshop; April 2006). In particular, there is collaborative problem-solving and collaborative decision-making between building technology system designers/professionals (as shown as Figure 1), rather than team members simply taking their assignments away to work on and bringing them back to be re-integrated. It has been proposed by some that integrated design process (IDP) could be equally called integrated decision-making (Zimmerman 2011).

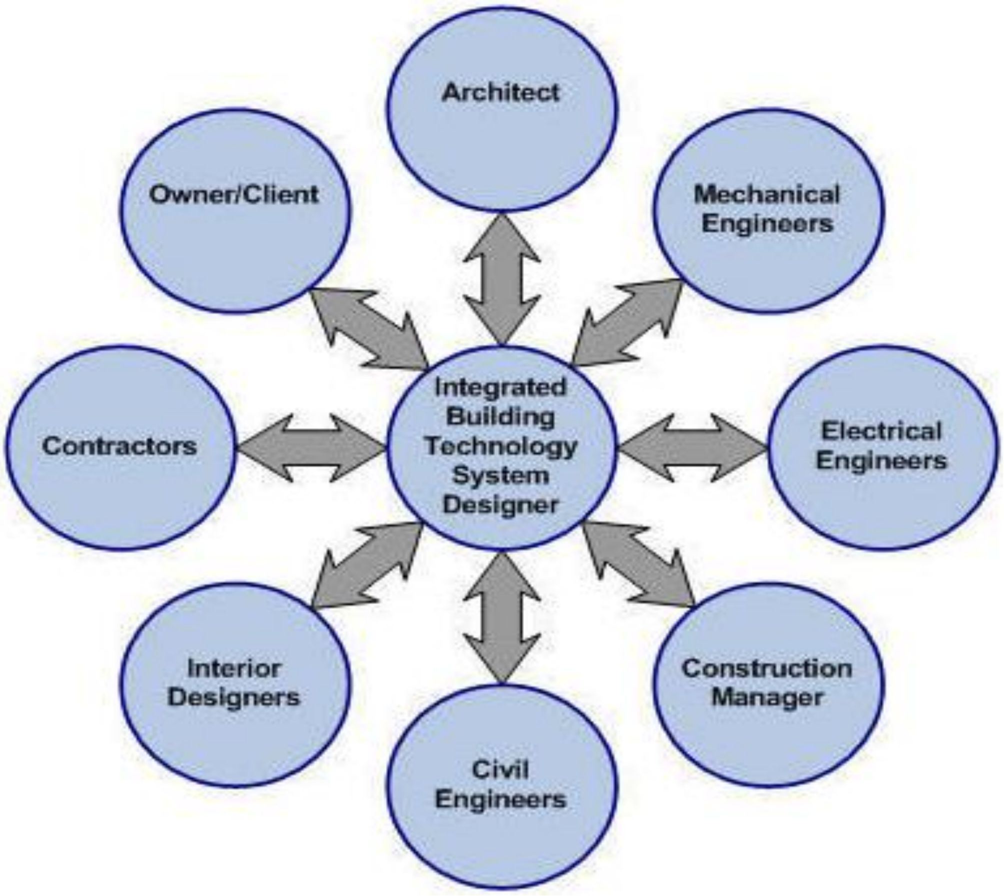
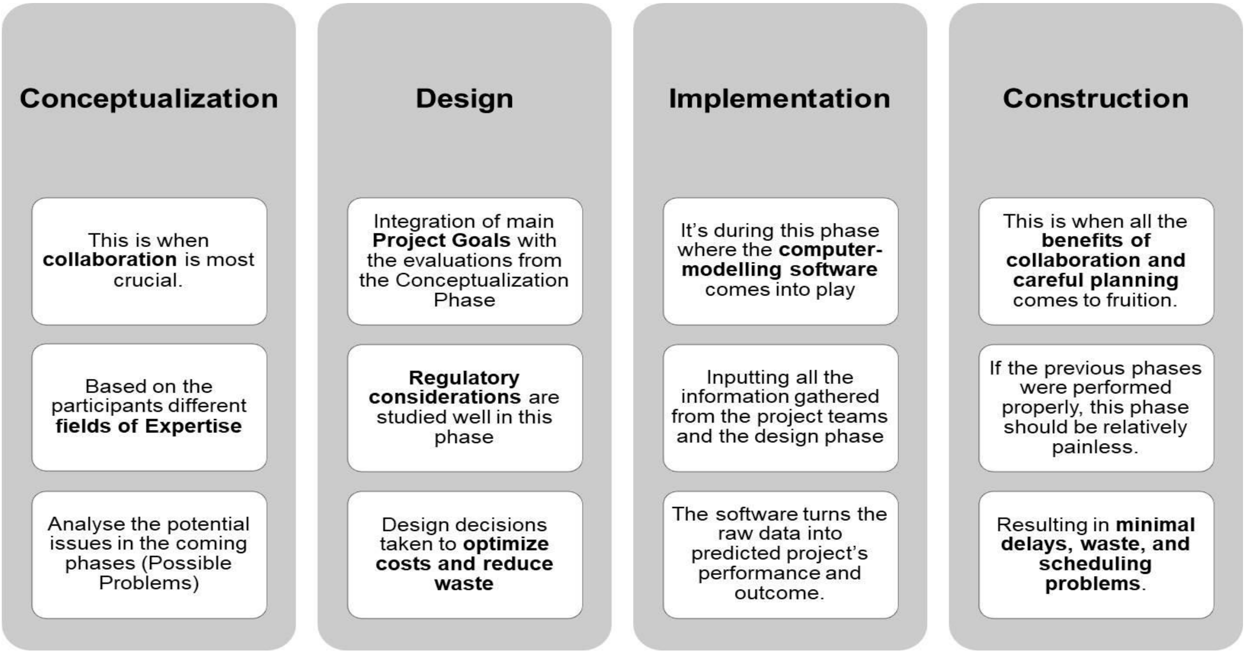


Figure 1: Integrated building technology system designers/professionals (Author)

Collaborative team members often work in parallel, with different distributed and heterogeneous architecture/engineering tools around the world. Concurrent architecture brings new ways of organizing design and execution/manufacturing activities, inducing deep modifications such as the concurrent realization of product life cycle tasks. This approach emphasizes the integration of all the disciplines that contribute to the project development, beginning in the earlier design activity so that important decisions are made considering the entire project life cycle (as shown as Figure 2). Concurrent architecture/engineering practices are applied to reduce time and improve the performance as a whole (Slimani et al. 2006).



Conceptualization	Design	Implementation	Construction
This is when **collaboration** is most crucial.	Integration of main **Project Goals** with the evaluations from the Conceptualization Phase	It's during this phase where the **computer-modelling software** comes into play	This is when all the **benefits of collaboration and careful planning** comes to fruition.
Based on the participants different **fields of Expertise**	**Regulatory considerations** are studied well in this phase	Inputting all the information gathered from the project teams and the design phase	If the previous phases were performed properly, this phase should be relatively painless.
Analyse the potential issues in the coming phases (Possible Problems)	Design decisions taken to **optimize costs and reduce waste**	The software turns the raw data into predicted project's performance and outcome.	Resulting in **minimal delays, waste, and scheduling problems**.

Figure 2: Phases of IDP project life cycle (Author)

Architects/engineers have long understood the performance benefits of collaborative problem-solving and integrated design process. When the whole design team works closely in early design, the result is often reflected on wellbeing (as shown as Figure 3); big reductions in energy use, better daylight performance, and improved thermal comfort, often without increasing capital cost that lead to more control over design as following (Slimani et al. 2006; Zimmerman 2011):

1. Capital cost savings.
2. Improved project delivery.
3. Improved architect/engineer workflow.
4. Improved occupant wellbeing.

Figure 3: Benefits of collaborative problem-solving and integrated design process on improve wellbeing (Author)

Integrated design process in construction projects creates a foundation for increasing efficiency, by good communication, transparency, and a focus on the overall project delivery method (as shown as Figure 4). This design is considered as game-changing design solutions that greatly benefit owners and result in more fulfilling outcomes for all team members involved (Slimani et al. 2006):

- Iterative nature: one of the biggest benefits of the integrated design process is that it eliminates Random Acts of Design (RAD).
- Minimizes the risk: with integrated design system, companies take the risk of guaranteed price and ensure that the client's project does not go penny over the assigned budget.
- Design from a developed perspective: Owner's Project Requirements (OPR) documents the top priority list for any successfully integrated design process.
- Cost-shift investment: project teams often try to overcome the challenge by cutting areas that have a more long-term impact.

Figure 4: Integrated design process in construction projects delivery (Author)

Collaborative problem-solving facilitate Integrated Project Delivery (IPD) to open communication and build trust in the relationship, as collaborators discover that all are working together for a shared outcome. This increases the joint commitment in the relationships and in the organization. It also indicates a commitment in helping others in order to reach their goals and objectives, also to improve everyone's performance in the development of the project (as shown as Figure 5). Moreover, collaborative communication encourages in finding creative solutions. This increases the likelihood that others will take the ownership of an issue and its solution (Daigle et al. 1996; Zimmerman 2011).

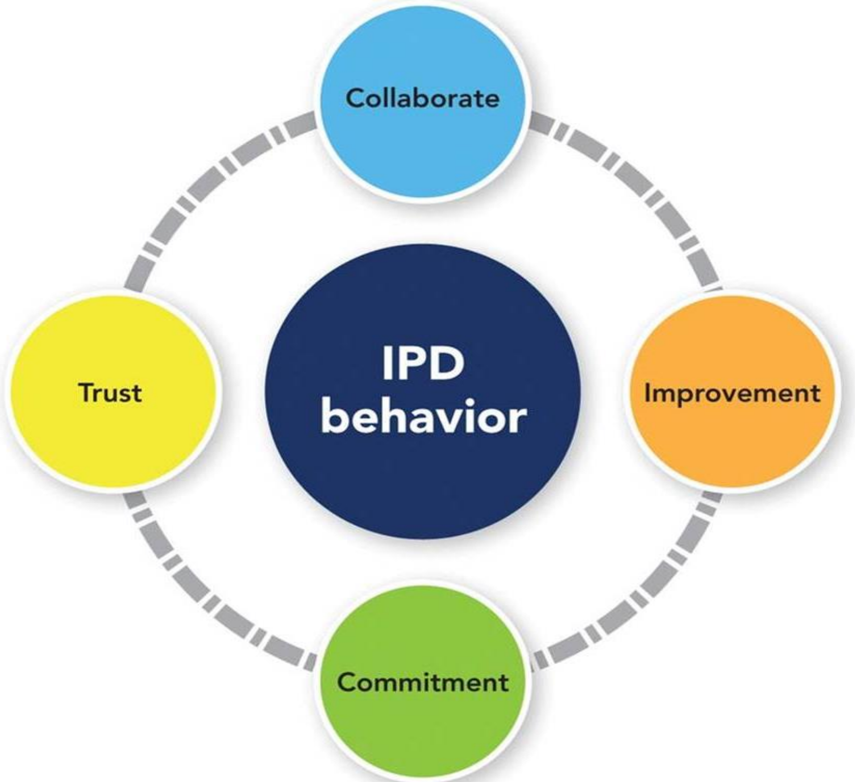


Figure 5: Integrated project delivery (IPD) behavior (Author)

The National Science Foundation NSF (1994) task force report states that the ability to work in groups is an expected skill of graduates. Although the recent curriculum documents call for such activities, the recommendation for the early use of groups is often ignored. Choosing a collaborative approach in education is a departure from the traditional model of the controlled, as lecture-driven classroom is familiar to most instructors and students. Collaborative approach contrasts with the traditional approach in terms of the attributes of each. The traditional approach is characterized by: competition, focus on one's own work, destructive criticism of others, manipulation of the system for one's benefit, and a general lack of trust. The collaborative approach is characterized by: cooperation, compromise, flexibility or roles, trust and respect of others, questions as well as constructive criticism, and group problem-solving (Daigle, et al. 1996).

The use of groups and teams is not without perceived disadvantages; MacGregor (1992) identifies seven belief shifts that must take place to enter into such a collaborative problem-solving learning environment (Daigle, et al. 1996; Fiedler 2009):

1. From listener, observer, and note taker to active problem solver, contributor, and discussant;
2. From low or moderate expectations of class preparation to high ones;
3. From a low-risk, private presence in the classroom to a public one with many risks;
4. From attendance dictated by personal choice to attendance dictated by community expectations;
5. From competition with peers to collaboration with them;
6. From responsibilities and self-definition associated with learning independently to learning interdependently;
7. From notions that teachers and texts are the sole sources of authority and knowledge to the notion that peers, oneself, and one's community are additional and important sources of authority and knowledge.

Students and instructors must be guided in making this transition to overcome the bias for the traditional approach. The use of groups often results in greater time demands. These collaborative skills do not occur spontaneously. Research has shown that process related issues of group activities consume as much faculty time as issues related to course content. Dysfunctional group behavior often occurs when members have not mastered a common problem-solving strategy or are not synchronized among the members. Another major concern is that of accountability. Slavin (1990), cautions that both group goals and individual accountability are essential in a collaborative environment. The influence of individual psychological types in group situations also is a potential source of communication dysfunction if not properly managed. Thus the individual psychological types of team members influence the effectiveness of teams applying formal problem-solving methodologies (Daigle, et al. 1996; Peacock 2009).

Learning is more active and more effective when students work in peer groups to develop problem solutions and reach the results. The instructor cannot leave the use of collaboration to chance, but must establish an environment conducive to collaboration and encourage the student's transition from passive listener to active contributor. The instructor should create a "culture" in which groups can succeed. Therefore, the instructor's responsibility is to train, guide, and manage the activities of the groups. Curricula documents call for the use of groups; researches demonstrate the benefits of collaborative learning environments. However, individual skills, especially problem-solving skills, cannot be sacrificed for a collaborative approach (Daigle, et al. 1996; Wiersma & Henry 2005).

The main theoretical basis for designing the collaborative problem-solving (CPS) learning goals, which proposed by the Organization for Economic Co-operation Development (OECD) are obtaining inter-correlations for the students' performance to assess the overall collaborative problem-solving skills, which could be as follows (Daigle et al. 1996; Wiersma & Henry 2005; Fiedler 2009):

1. Establishing and maintaining shared understandings.
2. Taking appropriate action to solve the problem.
3. Establishing and maintaining team organization.

An integrated team in an integrated design studio offers distinct advantages when compared to the traditional project team. If, as Zimmerman says, "the future of building design is found in IDP", then a better future for the IDP is found in the activities of an integrated design studio (Wiersma & Henry 2005; Zimmerman 2011). Unfortunately few teams possess these attributes (as shown as Figure 6). For example, some team members may work more than others or complete entire projects by themselves, but their efforts go unnoticed. This scenario can lead to workplace conflicts, frustration and loss of motivation (Slimani et al. 2006).

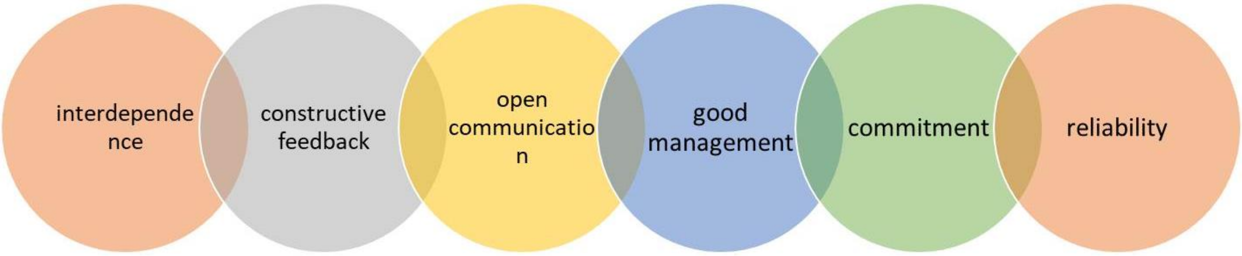


Figure 6: Successful teamwork's key attributes (Author)

3. Thermal retrofit in historical built environment

3.1. Thermal retrofit impact on health and wellbeing

The term built environment, or built world, refers to the human-made surroundings that provide the setting for human activity, ranging in scale from buildings to parks. It has been defined as the human-made space in which people live, work, and recreate on a day-to-day basis. The built environment encompasses places and spaces created or modified by people including buildings, parks, and transportation systems. In recent years, public health research has expanded the definition of built environment to include healthy food access, community gardens, and mental health. Within the field of public health, built environments are referred to as building or renovating areas in an effort to improve the community's wellbeing through construction of aesthetically, health improved, and environmentally improved landscapes and living structures (Hensel 2010; Aelenei et al. 2011).

Thermal comfort according to the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) is "That condition of mind which expresses satisfaction with the thermal environment and is assessed by subjective evaluation". There are two main approaches to thermal comfort: the steady-state model and the adaptive model. The adaptive model is mainly based on the theory of the human bodies adapting to its outdoor and indoor climate. In addition to three adaptive thermal comfort standards that are comprehensively reviewed: the American ASHRAE 55-2010 standard, the European EN15251 standard, and the Dutch ATG guideline. Although thermal sensitivity varies from one person to another, according to age, gender, activity, cultural habits, etc., the basic principles behind thermal comfort are largely universal (Taleghani et al. 2013). Thermal comfort is experienced via number of conscious interactions between three personal and environmental factors: Physiological: the way our bodies work and interact with our environment; Physical: the main parameters of the environment around us (air temperature, air humidity, air movement, and room surface temperature); Socio Psychological: the way we feel as a whole (tired, stressed, happy, etc.) and the kind of social environment we live in (Taleghani et al. 2013; Du et al. 2015).

Thermal retrofit have received increased attention in recent years as a result of constant concerns for energy supply constraints, decreasing energy resources, increasing energy costs and rising impact of greenhouse gases on world climate. Promoting whole, building strategies that employ passive measures with energy efficient systems and technologies using renewable energy (Torcellini 2006; Aelenei et al. 2012; Du et al. 2015). What was not identified in any of the studies was the need for assessing the impacts of building retrofit measures on occupant health and wellbeing. For example were there any changes in indoor air quality and also thermal comfort, and how did they affect the building and subsequently the occupants themselves? Are occupants healthier post retrofit, or have they experienced any health issues? Of particular concern is the highest exposure for wind driven rain and therefore any retrofit measures of insulation to the exterior façade could have unintended consequences of moisture crossing the exterior face onto the interior face of exterior walls. As a result this potential moisture ingress can impact upon internal occupant comfort. Therefore, thermal retrofit is seeking to improve the monitoring and evidential base of information in relation to the impact of retrofit energy efficiency measures in relation to general health and wellbeing, the improvements in energy performance and reductions in carbon emissions, and thus alleviation from fuel poverty and impacts upon health and wellbeing for occupants (Sartori 2012; Wimmers 2012; Littlewood et al. 2017).

The impacts of retrofits on health and wellbeing varied by buildings, mainly including: 1) full facade (including the base) thermal insulation (usually 20-30 cm of Expanded Polystyrene EPS or in some cases mineral wool on external walls); 2) roof thermal insulation (solar collectors were installed on the top of the roof in some cases); 3) improving heating and hot water systems (e.g., replacement of heating system trunk pipelines with new ones, new thermal insulation for piping system); 4) improving ventilation and heat recovery systems (e.g., new fans in attics/roofs; installation of adjustable air vents on the top part of the plastic windows; 5) replacement of old windows with more efficient windows, glazing of balconies or terraces, replacement of doors, etc. (Du et al. 2015; Littlewood et al. 2017).

3.2. Thermal retrofit of heritage and historic buildings

Retrofitting means; providing something with a component or feature not fitted during manufacture or adding something that it did not have when first constructed, while energy retrofit is recognized as a measure to help with protection of heritage by providing healthy indoor environments that can have a longer lifespan. Retrofits in places of cultural and historical significance are often described as a balancing act between optimization and conservation of original features. The concept of thermal retrofit considers upgrades to energy efficiency and thermal comfort, in the building stock does not provide adequate indoor comfort conditions (Besen & Boarin 2018).

Thermal retrofit of historic and heritage buildings or improve environmental quality in historical built environment can take place when the buildings have elapsed useful life or are reaching their end of useful life (as shown as Figure 7&8), and it take place in three conditions; conversion of heritage buildings, adaptation of building's function, and reconstruction of damaged buildings. (El-Darwish & Gomaa 2017):

Figure 7: Christchurch Cathedral after the Earthquakes in 2011 (Telegraph 2011)

Figure 8: URM Building on Barbados St. Damaged after the Earthquake (Schwede66 2011)

The improvement of envelope thermal insulations, lighting and glazing, where thermal performance of a building relies on its ability to resist air penetration as well as its ability to prevent heat exchange through structure. Therefore, if retrofit is applied on energy efficient retrofit methods at the building envelopes, annual fuel cost would be reduced approximately one-third of the current situation of the building. Also, off-the-shelf thermal upgrade measures with suitable attention to detail to design, specification and installation can realize the reduction in U-values anticipated, and hence it can significantly reduce heat requirements for space and in term CO2 emissions. As well by envelope retrofit, efficient solar protection, high thermal inertia, and hybrid ventilation strategies; in addition to domestic water heating, photovoltaic panels and solar thermal air conditioning (a combined strategy of retrofit) achieved up to 83% total reduction in electric energy demand. Thus, building retrofit objectives can be recognized as follow (El-Darwish & Gomaa 2017; Besen & Boarin 2018):

- Make buildings more thermal efficient and sustainable.
- Help cut carbon emissions.
- Contribute to overcoming poor ventilation and damp problems, therefore improving the health of occupants.
- Improved energy efficiency.
- Increased staff productivity.
- Reduced maintenance costs.
- Decrease 40% of total energy consumption.
- Increase building adaptability, durability and resiliency.
- Improve amenities for the building's occupants and improve the performance of the building.

Hence, building and environmental conditions from outdoor to indoor, whose variation may influence the inter-coupled variables (as shown as Figure 9), are outdoor air temperature, solar radiation in environmental conditions; radiation cooling/heating and ventilation type in HVAC systems; internal heat gains and schedule of occupancy and operating conditions; wall, ceiling, floor and window to wall ratio's (WWR) of building envelope properties; and finally floor area and ceiling height in building size can determine the whole building thermal and indoor airflow behaviors, whereas individual characteristics may have distinctive influence (El-Darwish & Gomaa 2017):

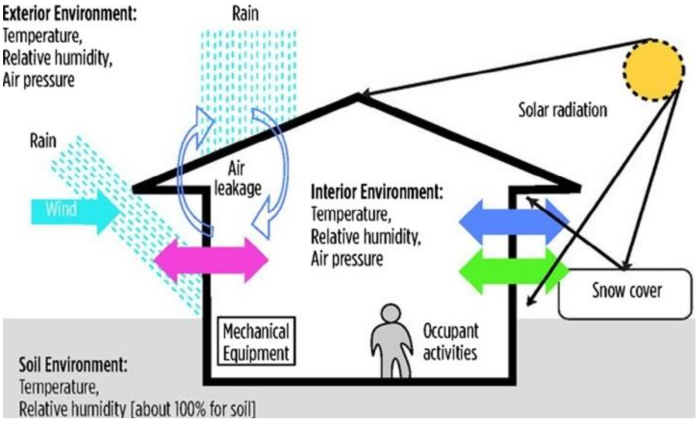


Figure 9: Environmental Variables that can affect the Interior of Buildings (Les Bodwell 2012)

Thus, thermal comfort that plays a major role in energy consumption can be achieved through adding slight modifications to previously constructed buildings, and by the use of the following selected issues based on their efficiency and feasibility for retrofit (El-Darwish & Gomaa 2017; Li et al. 2017):

1. Insulation and thermal bridge.
2. Air tightness and infiltration.
3. Window glazing.
4. Solar shading.

4. Methodology

Architectural heritage is a valuable asset and its adaptation to future is an important aspect that contributes to its preservation. This paper has provided an overview on issues and opportunities related to thermal retrofit of historic built environment generally, and heritage buildings in Lebanon particularly, providing the basis for subsequent stages of this research. The study will handle the great importance of developing critical thinking and communication skills in teaching-learning methods and strategies, in addition, to collaborative problem-solving methods to improve education performance. The research depends on a systematic methodology via reviewing the thermal retrofit in historical built environment. Moreover, it will illustrate thermal retrofit impact on health and wellbeing, especially in heritage and historic buildings.

The paper concludes with a realistic case study (Thermal Retrofit of Tripoli Old Souks, North Lebanon) in which the proposed "interactive" teaching-learning strategy in architectural education has been trilled. This strategy suggests a framework based on critical thinking and collaborative problem-solving methods in four phases: analyze the historical built environment of the study area (Tripoli Old souks in north Lebanon) in different historical periods, identify the problem of the study that can negatively affect Lebanon, review in international attempts of thermal retrofit in historical built environment, and finally an application of thermal retrofit in the study area (students' final submission), to enhance health and wellbeing with preserving the cultural and architectural heritage, in addition to, the context image and social activities of these historical built environment. The experiment was conducted in Beirut Arab University, Tripoli branch, Lebanon on a mandatory course (History of Architecture III) for Faculty of Architecture - Design & Built Environment students. The sample was 27 students of the 3rd level that were attending the fall semester, academic year (2019-2020).

5. Case study critical thinking and collaborative problem-solving to improve education performance

For the purposes of this paper, the researcher is considering the group activity involved in critical thinking accompanied with collaborative problem-solving as part of architecture students' education in Beirut Arab University on a particular course (History of Architecture III, 3rd year students). Specific intervention will be implemented to improve environmental quality in historical built environment (Thermal Retrofit for Old Souks of Tripoli, North Lebanon), which will increase the awareness for the students of health, and wellbeing aspects and its impacts on conservation aspects of architectural heritage. In addition to, spread the spirit of teamwork to facilitate the concept of integrated design process between the different disciplines, which will expose them to a real problem in a realistic situation.

This teaching-learning method will be experimented through four phases: the first is an archival review to analyze the historical built environment of the study area (Tripoli Old souks in north Lebanon) at different historical periods. The second is an analytical review to identify the problem of the study. The third is an identical review for international attempts of thermal retrofit in historical built environment. The fourth is an application of thermal retrofit in the study area with the continuity of conserving the architectural heritage to ensure health and wellbeing of historic built environment in Lebanon. As a result of the interactive strategy in architectural education and by comparing the outcomes before and after assessment of students' level, it is obvious that applying critical thinking and collaborative problem-solving increased the environmental awareness for the students, which is completely distinct from the ordinary methods on research activity, where it becomes clear after this experiment a radical change in students activity occur, the way of thinking, outputs, solutions and proposals that were distinguished in greater depth.

5.1. Phase I (Analyzing the historical built environment of the study area in Lebanon)

The instructor with the third-year students divided into groups illustrates and analyzes the historical built environment of the study area (Tripoli Old Souks in north Lebanon). Tripoli is considered as Lebanon's second capital. It is situated 85 km north of Beirut along the Mediterranean coast; the city was founded on the Mediterranean seaside during the 14th century BCE. It was not until the Middle age that Tripoli became a city with two poles: the marine city (El-Mina); original site of Tripoli, and the Medina; currently the Mamluk core (Tripoli Old Souks). In 1289 the Mamluk conquered the crusader city that was situated on the peninsula and razed it to the ground and built a city at the foot of the crusader citadel along the Abu Ali River, around 3 Km to the west. This strong structure can clearly be seen as a form of historic built environment that largely determines cultural and architectural heritage (Ginzarly & Teller 2016).

In 1953 the Directorate General of Antiquity (DGA) in Lebanon asked UNESCO to conduct an urban study about the Mamluk core in Tripoli. They identified 44 monuments that should be conserved. Moreover, the survey was very punctual and was centered on specific buildings treating them as frozen icons that stand alone in the architectural heritage without looking at different social and spatial relationships between the built and the natural environment. The selection of listed buildings was mainly based on age, function, and architectural characteristics of the buildings. Selected buildings are religious and public buildings include the citadel, churches, mosques, khans, schools, and public baths. The mission recognized the historical significance of residential houses and their role in constituting the specific character of the city but it did not include these in the list. In 1955 under the surveillance of the Association for the Preservation of the Archaeological Heritage of Tripoli a new heritage survey was conducted. This time the scope of heritage was extended to include sites, comprising cemeteries, gardens, residential blocks, and pedestrian commercial streets. This time the early Ottoman developments outside the boundary of the Mamluk core had its portion of listed monuments (Al-Harithy 2005; Ginzarly & Teller 2016).

5.2. Phase II (Identifying the problem of the study in Lebanon)

Thence, the instructor with the students starts to study and identify the scope of the problem, as Lebanon is suffering from multiple environmental problems due to the environmental mismanagement. NGOs, education, and the government are trying to raise the awareness of the Lebanese people. Unfortunately, this is not sufficient and is not reflected in their practices. The energy crisis in Lebanon is one of the most problems that need to be solved. Although the Lebanese people are suffering from the lack of electricity, yet they scarcely try to find ecological solutions in their buildings. International studies show that thermal retrofit of buildings will be an effective solution for both the government and the citizens. Thus, the application of such projects will be an efficient solution for the energy crisis that is facing Lebanon (Khoury & Khoury 2011; Ginzarly & Teller 2016).

For this reason, architects are considered an essential part of the solution i.e. increasing their attention to thermal retrofit will be positively reflected in finding solutions regarding this crisis, and will also improve the built environment, where the problem facing Lebanon after the civil war is concerning the ecological issues. Lebanese students in higher education and architecture schools programs are normally not even familiar with the term sustainability except some universities. Moreover, research proved that a handful of NGOs, global corporations, local businesses and the Ministry of the Environment are currently addressing ecological issues in Lebanon but on a surface level (Khoury & Khoury 2011).

5.3. Phase III (International attempts of thermal retrofit in historical built environment)

Then, the instructor and the participant groups began to study different international attempts of thermal retrofit in historical built environment. One of the international attempts was the Jama Masjid in the Kalbadevi neighborhood near Crawford Market at the South Mumbai region in India. The construction of the Mosque started initially in 1775 with rising of foundations on the tank (water reservoir) that was situated at this site in the midst of gardens and open land. The date of a one-story building completion (AD 1802 / AH 1217) and was erected over the tank and formed the original nucleus of the present Jama Mosque. A top floor was added with the munificence of a prominent Konkani merchant Mohammad Ali Roghay in 1814. The thermal retrofit of Mumbai Mosque decreased electricity Bill by 67% (as shown as Figure 10). It saved 35 tons of carbon dioxide (CO2) a year and switched to solar energy for 70% of its electricity requirements, which made Jama Masjid to have the highest capacity to generate solar power, through 31-kilowatt power (KWP) rooftop solar system with 92 panels that was installed in the mosque. This thermal retrofit will help not only the mosque, but also the areas around the city that don’t get sufficient supply of electricity. They have installed a net-metering system, which will export the surplus power generated by solar back to the grid (Bhardwaj 2017).

Figure 10: International attempt 1; thermal retrofit for improving the Mumbai Jama Masjid in India (Author & participant students)

Another international attempt was the St. Michael and all Angels Church in Withington, England. The current structure, the third church building on the site, was built between 1879 and 1881 although parts of the original medieval church building (chapel has existed on the site since 1488), notably the tower, survive from earlier periods. This house of worship has undergone a thorough thermal retrofit to become Britain's first zero carbon church (as shown as Figure 11). Featuring a biomass boiler for heat, and a solar array on the roof, the church is now running on 100% renewable energy. The 12th century building is now powered entirely by renewable energies: the solar energy is generated with 24 solar modules with a total output of 3.12 KW, which are installed on the roof of the church. The modules were carefully installed to meet strict regulations concerning historical buildings by using a special ladder system that did not affect the structure of the building or the visual appearance. Given that many churches were traditionally built on a strict east/west axis, they have plenty of south-facing roof space that is ideally primed for solar energy (Grover 2012).

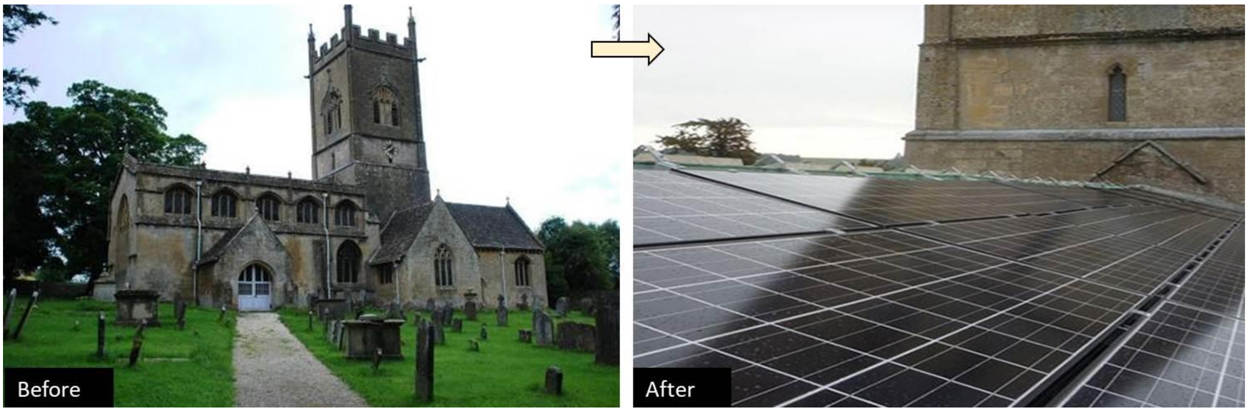


Figure 11: International attempt 2; thermal retrofit for improving the St. Michael and all Angels Church in Withington, England (Author & participant students)

5.4. Phase IV (Thermal retrofit to ensure health and wellbeing of historic built environment in lebanon)

The students with the aid of their instructor worked on special design criteria for improving environmental quality (thermal retrofit) to ensure health and wellbeing aspects of historical built environment, specially, within the study area (Tripoli Old Souks in north Lebanon). For example, one of the participating groups created solutions for improving the Taynal Mosque in Tripoli, Lebanon, which is an oblong structure of sandstone, and have been founded by Sayf ad-Din Taynal an-Nasiri al-Ashrafi (d. 1343), he was a prominent emir "prince" and Mamluk of an-Nasir Muhammad, the Bahri Mamluk sultan of Egypt. He served as the nawab "sovereign ruler" of Tripoli for three terms, and Gaza for one term, in the mid-14th century during the reign of al-Nasir Muhammad. He ordered the construction of the Taynal Mosque in Tripoli in 1336. The Mosque peculiarities reflect the remnants of a Crusader church built by the Carmelite Fathers at the time of the Crusades. Their design criteria include the installation of photovoltaic solar panels and solar thermal power plants, the reduction of drinking water consumption, the conversion of lighting and the installation of a centralized technical management system. This last mechanism will facilitate the control of various installed equipment and control doors. Through these certain modifications, students were able to resolve the problem (as shown as Figure 12).

Figure 12: Sample 1; thermal retrofit for improving the Taynal Mosque (Author & participant students)

Another example, other participant group created solutions for improving the Mansouri Great Mosque in Tripoli, Lebanon, which also known simply as the Great Mosque of Tripoli. It was built in the Mamluk period, from 1294 to 1314, around the remains of a Crusader Church of St. Mary. In any case, the two Christian elements in no way detract from the traditional Muslim nature of this great royal mosque, the first building erected in Mamluk Tripoli. The Mansouri Mosque was named after the Mamluk sultan who conquered Tripoli from the Crusaders in 1289, al-Mansur Qalawun. The mosque itself was erected by his two sons, al-Ashraf Khalil, who ordered its construction in 1294, and al-Nasir Muhammad, who had the arcade built around the courtyard in 1314. Their design criteria include installing a vertical PV system to make renewable energy in the wind direction, composing solar panels on the roof of the building to make renewable energy through the sun direction, and closing the arched openings by low-E glass to enter more light and reflect the heat. Through these certain modifications, students were able to resolve the problem (as shown as Figure 13).

Figure 13: Sample 2; thermal retrofit for improving the Mansouri Great Mosque (Author & participant students)

6. Conclusion

Action should be taken to solve the energy crisis problem, and students should be ecologically literate. For example, the focus of Beirut Arab University in Lebanon is to let staff members, researchers and students support their researches and projects by environmental studies and inspire concepts from environmental approaches, based on the capability of its Environmental Labs.

Whereby, the most significant development challenges of sustainability are associated with climate change, global poverty, social and economic inequality, population growth, as well as, demographic changes and adaptation to rapid global economic changes. Hence, the role of architects, decision makers, and engineers working in the domain will acquire further significance.

The research has addressed a limited scope within the quest of viable strategies to achieve thermal retrofit, therefore, energy consumption for historical buildings of the study should be measured after using retrofit strategies (double glazing, air tightness, external wall insulation, and solar shading), to conclude how much is energy reduced by regular/simulation-based measurement tools, in order to ensure that the proposed solutions of building thermal retrofit within the historical context have been succeeded on health and wellbeing with the continuity of conserving the architectural heritage.

As a broad perspective, it could be concluded that retrofit strategies of historic built environment affects human comfort and hence energy consumption which is a vital one, also needs to be considered/addressed through a number of recommendations, guidelines and special measures, as follows:

- Encourage historic building thermal retrofit technologies that can reduce cooling energy demands, although in some case it can decide cooling appliances as unnecessary.
- Further studies can be made in order to enhance thermal human comfort or to address the cost-effective measures on short term and long term.
- Retrofit measures can target visual comfort or other human comfort issues.
- Support research on new innovative materials and techniques that can reduce energy consumption.
- Support other retrofit strategies on historic built environment and study their cost effect on long terms.
- Different types of buildings can also be studied.

Furthermore, the use of groups is accomplished throughout the curriculum, as well as larger more complex projects are addressed, the students will be better prepared to meet their career demands. The perceived benefits of the initial attempts at integrating the critical thinking and collaborative problem-solving in the curriculum are based on the observations and feedback, which can contribute in improving education performance as follow:

1. Teaching architecture students the literacy of ecology, in addition to applying in their design projects, will help in improving health and wellbeing and the ecological life attitude towards the community. This education will drive the students' attention towards ecological buildings, and subsequently thermal retrofit.
2. Architecture and construction work needs to foster environmentally friendly practices and students have to be aware of built environment glossary and practices.
3. The schools of architecture at the university level can inspire architecture students as well as encourage and support ecological designs that incorporate sustainable thinking in their design projects.
4. Enhancing the importance of sustainability in buildings design would drive the students' attention towards the environment as well as the community.
5. The integrated design process IDP with operations and training provides stronger wellbeing integration than either might achieve in isolation.
6. When people work together, they can share ideas, provide feedback and keep each other accountable. Teamwork allows for brainstorming and often leads to better decision-making. Employees can share the workload and help each other, which leads to greater productivity and faster turn-around times.

7. Strengthening the socio-cultural aspects in research and education curricula will create new sustainable solutions for human, urban, industrial and business, thereby reflected on health and wellbeing in the built environment.

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