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The Integration of Building Codes into the Architecture Design Process

Dr. Ahmed Cherif Megri, North Carolina A&T State University

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Ahmed Cherif Megri
North Carolina A&T State University
Civil, Architectural and Environmental Engineering Department
Email: ac_megri@hotmail.com

Abstract:

In this paper, we explore new methods, to deliver a better design, through demonstrating how the building code requirements can be integrated and associated to the architecture design process, using real case studies. Two case studies from the work developed by students over two courses will be introduced and discussed in details. A flow chart representing a comprehensive design process that includes the architecture, as well as the building code integration aspects will be presented and discussed.

The argument of the paper will be based on the International Building Code (IBC 2012) which is issued by the International Code Council (ICC) and considered as the most comprehensive and coordinated national model code in the US and is currently commonly used and enforced in 44 states. The paper will also examine and report on the purpose, types, interpretation, understanding and use of building codes applied in the United States.

We discuss the courses from students' point of view, and the experience earned in design, code development, and also in written and oral communication skills. Future plans to evaluate the effectiveness of these courses in term of learning outcomes.

1. Introduction:

Architecture design process consists of conceptual design phase, schematic design, design development and finally construction documents. This process starts with reviewing and evaluating the owner's building program and budget requirements and finish with providing graphic and written information necessary for bidding, construction and future building management. This architecture process is not complete unless it includes the appropriate and numerous building code requirements that touch all design phases and building components, such as building area and height limitation, type of construction, the size and type of openings, number of exits, travel distance and paths of exit, fixture counts, fire-resistive construction, interior finishes, and so on.

Very often the architectural design, energy, lighting, building code are learned differently and in different stage of the curriculum. In this paper, our objective is to combine both the architectural aspects, as well as the building code requirements in different phases. Very few works have been developed to address the application of the building code during the design process. John Ruskin (2011) described process step-by-step.

In this paper our objective is describe the integration of the building code into architecture design process. A comprehensive case will be presented.

2. Methodology:

2.1. Conceptual Design Phase

After reviewing and evaluating the owner's building program and budget requirements, the designer provides the owner with alternative approaches to the design and construction of the project. The designer prepares various design schemes and a detailed design program listing all the spaces, functions, estimated areas, preferred adjacencies and inter-relationships. The results will be in a form of small-scale preliminary sketches of overall form of the building, the massing, relationship diagrams and an outline of the building in relation to the site and possibly a simple sketch of the key sections and elevations. The designer presents these conceptual drawings to the owner in order to obtain his/her approval of a design scheme for development during the next phase.

During the preparation of design schemes, the designer should examine and revise the decisions taken during the previous phase and extend the analysis to the building code related issues at building and major space level.

2.2. Schematic Design

The design scheme selected by the owner is detailed during this phase. The designer will start identifying the criteria for the building materials and products, for exterior elevation finishes and for structural, mechanical and electrical systems based on the approved design criteria. Based on the design program and overall shape and form, the designer begins to locate and dimension major spaces at an abstract level. The designer presents the development of design to the owner in a format of plans, elevations, sections, renderings, perspectives, 3D models and basic detailing of particular areas. The owner also receives written documents, which provide preliminary project description, outline specifications and cost projections. During the schematic design phase, the building code analysis process continues in revising former building design data and checks all design decisions at floor and space level.

Jurisdictions adopt a building code (such as, international building code, Chicago building code, and so on) that is currently published (2012) or published previously (2009, 2006 or 2003). These codes may be amended to be more adequate to the actual situation.

This step is followed by assembling building data, such as building area, height and the number of stories, will affect the fire protection systems required, means of egress and so on.

Building's occupant group (s), mixed or single-use: based on activities, age, the possibility of having alcoholic liquor, a determination of the building's primary occupancy group can be made. Single, mixed, or separated occupancy of the building need to be identified.

The building need to be classified in which of the five types of construction is associated. For noncombustible (concrete or metal) construction the design team has several alternatives for construction type (I or II), depending on the level of fire-resistance (a or b) the team is willing to incorporate into the design.

If multiple occupancy groups are identified previously, then an initial decision needs to be made whether they will be treated as accessory, separated, or non-separated occupancies.

In the International Building Code (IBC, 2012), chapter 4 covers these situations and structures, such as malls, underground buildings, atria, high rises, parking garages, etc., called special use. If such situation exists, they need to be identified and identify the occupancy requirements that will apply from chapter 4.

Based on preliminary floor areas, determine occupant loads for each floor level using occupant load factors (maximum floor area in sq. ft. per occupant) in IBC Chapter 10, Table 1004.1.1.

Means of egress (chapter 10 of the IBC): The number of required exits for each floor level according to (IBC, 2012) Table 1021.1 is estimated based on the occupant loads. If more than one exit is required, ensure that at least two of the exits are remote from each other. The travel distances are estimated for each space to each exit and check that such travel distance is in accordance with code requirement (less than the maximum travel distance). In the contrary case, additional exit (s) is added until this distance is respected.

2.3. Design Development

The design development phase follows the approval of the schematic design and any necessary modification to the budget or the design program. During this phase, the design is further refined and detailed plans, sections, elevations and construction details are developed. The designer determines the type and size of equipment and focuses on technical issues, such as, constructability and integration of building systems and components. The space layout is now finalized to include its physical characteristics (length, height and depth) and material properties of walls, doors, windows, floor and ceiling. The outline specifications are revised after update of all of these design elements.

Before preparing the construction documents, the design has to be intensively checked against locally adopted building code and other design criteria related to circulation, energy, lighting and others preferred by the owner.

The intensive building code checking process covers every building code related items and details. The design data at this phase are considered “almost final”.

These data includes but not limited to:
- Occupancy and construction type of all spaces.
- Construction details that reflect the relation and connection between building materials and components.
- Layout and height of the building.
- Number, height and area of floors.
- Circulation routes including location, type and size of elevators, stairs and ramps.
- Intensive occupant load analysis.
- Number, type and size of exit doors.
- Travel distances to exit doors and areas of refugee.
- Locations, sizes and types of openings in exterior and interior walls.
- Level of fire hazards between adjacent spaces.
- Topological information (i.e. spatial relations between building components, such as separation, adjacency, connectivity & intersection).
- Zoning Ordinances and ADA related items.

For special situation, such as historical building, may apply for alternative solution at this level of the project, to respect the historical aspect of the building.

Determine where fire-resistive construction is required and which openings require protection. During this design phase, exterior wall assemblies are designed and evaluated, including the selection of materials. Based on construction type and fire separation distance (distance to the lot line or to the imaginary line separating the building to other adjacent buildings), exterior walls and openings may require some level of fire-resistive protection in accordance with IBC Chapter 7. Additionally, the thermal resistance of the walls is checked against the International Energy Conservation Code (IECC).

Interior finishes for floors, walls, and ceilings need to comply with several requirements, including fire and smoke performance characteristics of IBC Chapter 8 and sanitation requirements of IBC Chapter 12.

Establish the minimum widths of egress components, such as exits, stairs, corridors, and so on with the respect of the minimum size of each components (the minimum width of each exit is 32 in). As well, the accessibility requirements need to be satisfied (IBC chapter 10).

2.4. Construction Documents and Specifications Phase

The construction documents and specifications phase is considered the final design phase and it is based on the approved design development documents. The objective of this phase is to provide graphic and written information necessary for bidding, construction and future building management. All the documents produced during this phase in the form of drawings and specifications are considered as legal documents and should clearly illustrate the work, rights, duties and responsibilities of all parties involved in the construction process.

The designer is obligated to explicitly prove the project compliance with various adopted building codes by graphically presenting and textually affirming the description of every building component or detail related to issues addressed by the building code.

At this level of the project, several details are considered, such as:

- Means of egress: door hardware, stair riser and tread dimensions, design of handrails, and guards.
- Fire stopping and fire-resistant joints
- Fire extinguishers and their locations.

3. Case study

3.1. Building Description

The building selected for this case study is a library that was designed to bring all types of knowledge together in one space. It features a large, double height atrium for quiet reading and relaxation. There are trees located on either side of the atrium to assist in the passive cooling strategies of the building. The front of the atrium also acts as the circulation desk for the library.

Lining the atrium you can find seven types of rooms that serve all different purposes. On the northeast side of the building, next to the public restrooms, you will find a gallery space that is available to display the local artwork. The gallery can also serve as a waiting area for the adjoining lecture hall. As you move southeast through the building, you will come across two very large conference rooms that can be reserved.

On the opposite side of the atrium there is an all-purpose media room. This area is home to computers, televisions, DVD players, music stations, and much more. Next to the media room is a craft room where different families and organizations can share their knowledge and pass down techniques. Lastly, there is a children's reading center filled with books, tables, and play equipment.

All of the stacks are contained in the circular structure attached to the end of the atrium. A ramp spirals up three stories that holds all of the books, periodicals, etc. In the center, on the ground floor, there are numerous reading tables with task lighting. There are also five private group study rooms along the southwest wall of the stacks accompanied with more public restrooms.

Use: Central Library

The people of Port-au-Prince need a designate area where they can acquire all types of information. Their society relies on personal relationships where knowledge is passed down through generations. The only aspect hindering the expansion of knowledge is a building that can provide a central learning environment.

The building will house a culmination of all media sources and create a relaxed and organized environment for the city of Port-au-Prince. It will encourage lifelong learning and invite people to: come together to socialize, produce arts and crafts, teach classes, watch television, read books, listen to music, and so much more.

Class: A3 - Assembly

Location:
Port-au-Prince, Haiti (Cross streets of Rue de la Republique and Rue Lamarre)

Square Footage:

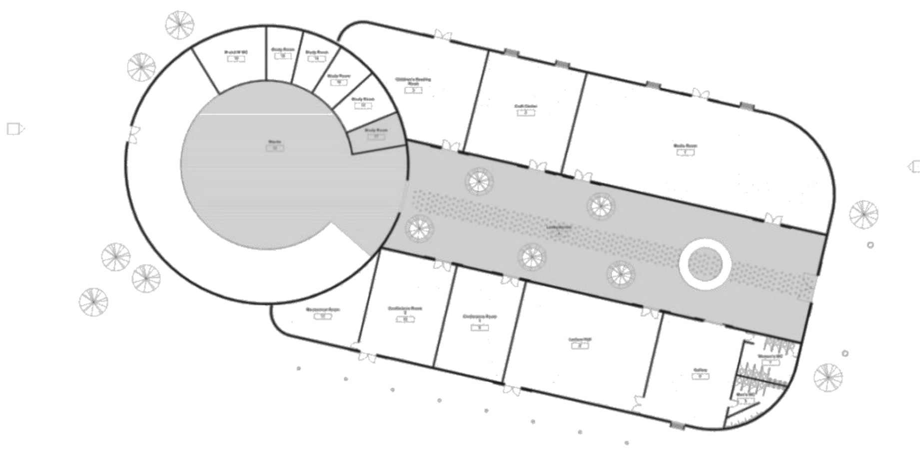
Space	*Area (sq. ft.)*
Atrium/Gallery	5,843
Restrooms	1,221
Stacks	6,180
Conference Rooms	2,042
Lecture Hall	1,847
Study Rooms	874
Craft Center	1,310
Reading Areas	1,000
Media Room	3,385
Children's Center	1,360
Copy Area	100
Mechanical Room	588
Corridors/General	1,106
Total	*26,856*

Construction: Type II A

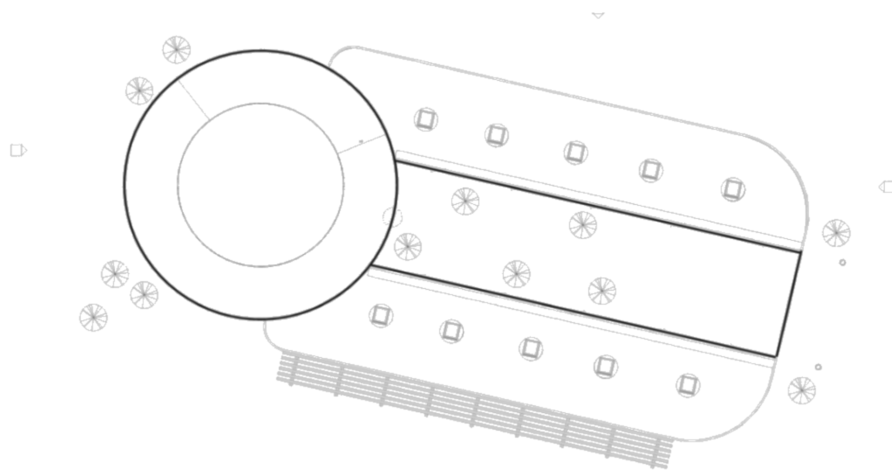
Roof	*R-Value*
Interiror Air Film	0.61
6" Concrete Slab	0.48
Waterproof Membrane	Nil
Root Barrier	Nil
2" Polystyrene	10.0
1" Drainage Board	Nil
1 ½" Soil	0.38
Exterior Air Film	0.17
Total	*11.64*

Building Height:
Triple Height Stacks: 42 feet; Double Height Atrium: 28 feet; Main Floor: 14 feet.

Circulation:
You enter the library through the glass double doors. From there, you can make your way through the atrium to the room of your choice. Each of the specialty rooms contains an emergency exit door to the outside of the building.



(a)



(b)

Figure 1: First (a) and second floor (b) plans of the building studied

Site: more than 55 feet from any other buildings.

Wall	*R-Value*
Interior Air Film	0.61
18” Reinforced Concrete Slab	0.80
2” Batt Insulation	6.28
½” Gypsum Wall Board	0.45
Exterior Air Film	0.17
Total	*8.31*

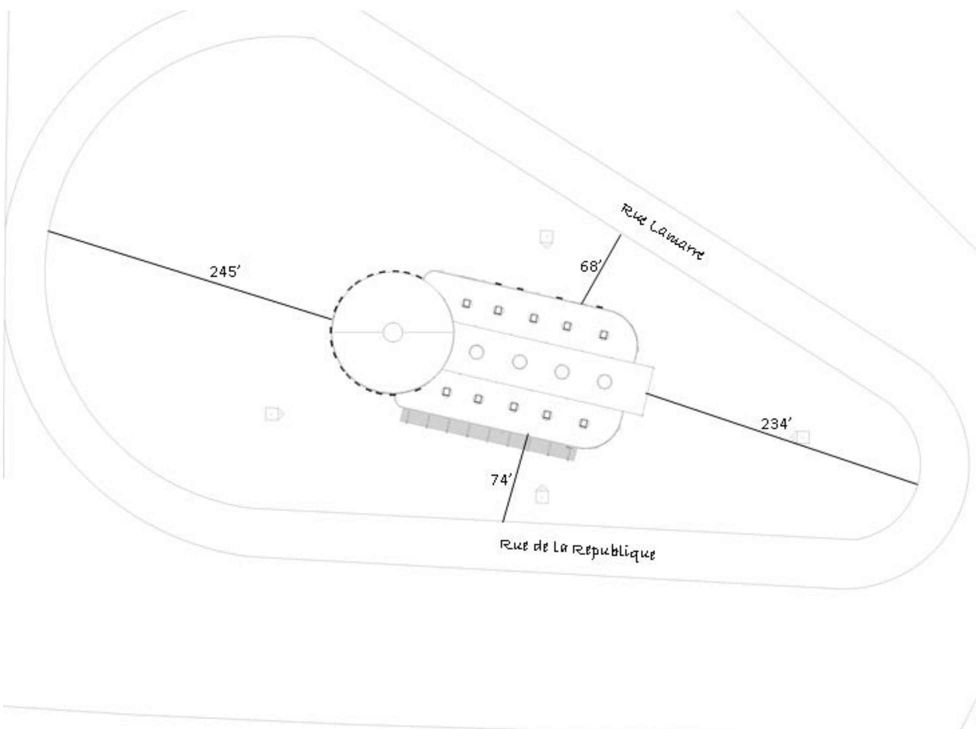


Figure 2: Site Plan of the building studied

Figure 3: The view of the building designed under Revit Program

3.2. Design Process:

Step 1: Applicable Codes

- The Port-au-Prince central library is located in Haiti. Currently, Haiti does not require any building standards, but I will design to the 2012 IBC.

Step 2: Essential Building Data

- See Appendix A – Building Description

Step 3: Building Occupancy

- Occupancy Class: A3 (Section 303)

Step 4: Construction Type

- The exterior and interior walls of the building will be made of precast concrete slabs with lightweight steel framing.
- Type IIA Construction

Step 5: Determine How to Handle Mixed Use Space

- All spaces will be treated as Occupancy A3.

Step 6: Special Use – Atrium

- The entire building shall have an automatic sprinkler installed (Section 404.3)
- There also needs to be a sprinkler at the ceiling level of the atrium since:
 Height = 42' < 55' (Section 404.3 Exception 2.)

- No smoke control system is needed since:
  Stories = 2 (Section 404.5 Exception)

- 1-hour fire barrier rating on all walls enclosing the atrium (Section 404.6)
  - See Appendix B – Wall Fire Ratings
  - The atrium is also used as the main corridor for the building and complies with fire resistance ratings per Table 1018.1

Step 7: Allowable Area and Height

- See Appendix C – Frontage Increase
- Sprinkler system installed

Step 8: Occupant Load (OL)

- Total OL = 867 (Table 1004.1.1)
  - See Appendix D – Occupancy per Room

Step 9: Establish Points of Exit

- Level of discharge exits:
  6 Exits > 3 Required Exits (Table 1021.1 with 501 < OL = 867 < 1,000)

- Separation distance complies with Section 1015.2
  - Two of the doors are located on opposite sides of the building

Step 10: Egress Pathways

- See Appendix F – Egress Pathways
- All routes from classrooms and within atrium are less than 250 ft. (Table 1016.1)
- However, the ramp that contains all of the books has a greater travel distance than 250 ft., and will need to be redesigned with a staircase and elevator core.
- The corridor meets the dead end requirements of Section 1018.4
  - There are exits located on either side of the corridor.

Step 11: Fixture Counts

- Required number of fixtures:
  $OL_{male/female}$ = 867/2 = 434

Water Closets (male) = 10 > 4 (1/125 per Table 2902.1)

Water Closets (female) = 14 > 7 (1/65 per Table 2902.1)

Step 12: Fire Department Access Roads

- According to the *International Fire Code*, access roads will need to be located.
  - Since we have not covered this in class, this step does not apply to the Port au Prince Central Library

Step 13: Design Changes

- Install sprinkler system throughout the entire building
- Redesign ramp in the stacks to meet egress pathways
  - Add stairs and elevator core
- Build fire access roads

Step 14: Fire Resistive Assemblies and Openings

- All *doors* located on the 1-hour fire barrier walls surrounding the atrium must also be rated at 1-hour (Table 715.4)
- All *windows* located on the 1-hour fire barrier walls surrounding the atrium must be rated at ¾ hour (Table 715.5)
- Skylights located on green roof require no protection
  - Distance from roof edge = 17' > 5' required without parapet

Step 15: Exterior Wall Assembly

- See Appendix A – Building Description for detailed wall section
- Wall section rated at 4-hours > 0-hours required (Table 720.1(2))

Step 16: Roof Assembly

- See Appendix A – Building Description for detailed roof section
- Roof section rated at 4-hours (Table 720.1(3))

Step 17: Interior Finishes

- Interior finishes used within the atrium space cannot be less than Class B (Section 404.8)
- All other enclosed rooms can use interior finishes of Class C (Table 803.9)

Step 18: Egress Widths

- See Appendix E for calculated door and ramp widths (Table 3412.6.11(1))
  - The two main exit doors must be split into four doors to comply with the maximum of 48" leave door.

Step 19: Fire Protection Systems

- The atrium is a double height space, but it does not connect more than two *stories*. Therefore, no fire alarm system needs to be installed as long as the occupant notification appliances will activate throughout the notification zones upon sprinkler waterflow (Section 907.2.14 and 907.2.1 Exception 1).
- Since an automatic sprinkler system will be installed throughout the entire building, a portable fire extinguisher will only be required in the media room (Section 906.1 Exception 1).

Step 20: Accessibility

- This building meets the accessibility requirements set forth by Chapter 11 of the International Building Code assuming all design changes specified in Step 13 are incorporated.

4. Survey and Course Evaluation:

The authors believe that this course is important in multiple ways. One important aspect is the fact that the course gives more opportunity to students to understand architecture design with "an engineer brain". Also, students understand that architecture is not only "an artistic" design, but also has other dimensions, such as safety, economic, and sustainability. The students learn about the importance to have a building that satisfies the codes requirements and not to use codes as design guide. The survey questions are:

Question 1: Do you feel the importance of this course to help you to be prepared for the industry? (Not at all Important, Very Unimportant, Neither Important or Unimportant, Very Important, Extremely Important)

Question 2: How you see the importance of this course to fill the gap between "architecture design courses" and "engineering design courses"? (Not at all Important, Very Unimportant, Neither Important or Unimportant, Very Important, Extremely Important)

Question 3: The importance of the project to help you understand the codes concepts? (Not at all Important, Very Unimportant, Neither Important or Unimportant, Very Important, Extremely Important).

Here, responses of design students to Questions 1, 2, and 3 are summarized (Figures 4 to 6). In this survey, we can see how the students believe have be shifted in all the 3 aspects surveyed. The survey focuses only on global questions regarding the course. A detailed questions need to be surveyed in the future to recognize the importance and also how to improve different aspects of this course.

In parallel with the self-evaluation of each course by the instructor, we also conduct a course evaluation by students. This topic is a part of the HVAC laboratory course. The course objectives introduced earlier in the course are again provided to the students at the end of the semester. The students' input on whether the materials offered have met the objectives is then complied and used in the program outcome assessment process. Results of instructor course evaluations (conducted by students) are reviewed by the Department Chair and the Dean and shared with the faculty.

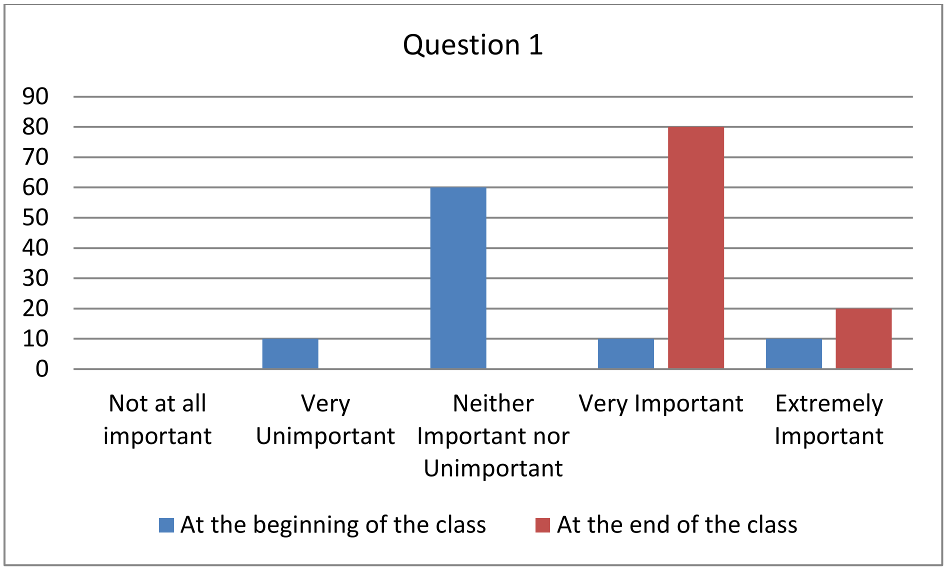


Figure 4: Do you feel the importance of this course to help you to be prepared for the industry?

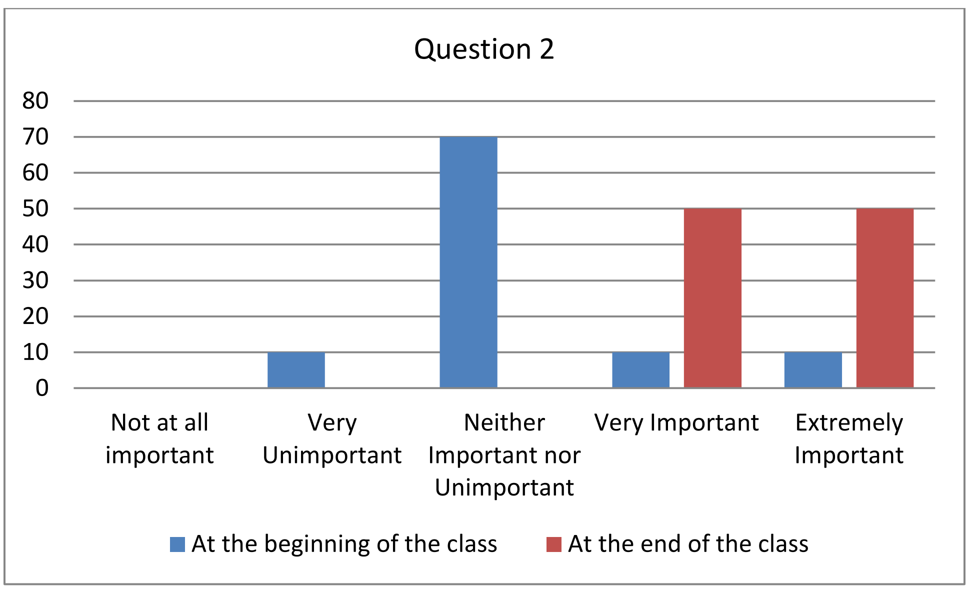


Figure 5: How you see the importance of this course to fill the gap between "architecture design courses" and "engineering design courses"?

Each faculty member also conducts an evaluation of performance of students in his/her courses as part of the Program objectives and outcome assessment process. A summary report on the performance of students (to meet the Program objectives) and compliance with the Program outcomes is prepared and submitted to the Department Chair for the assessment purposes.

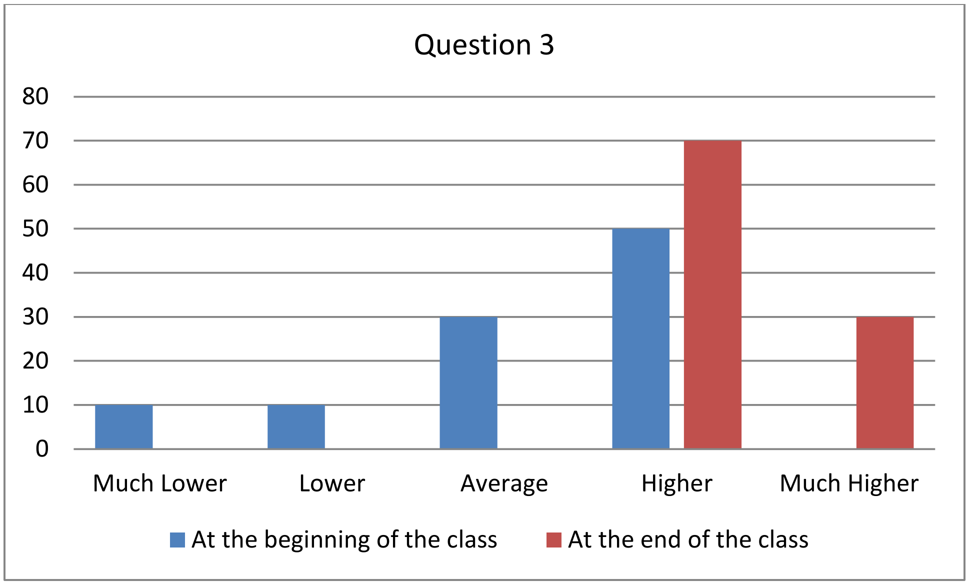


Figure 6: The importance of the project to help you understand the codes concepts?

Future plans to evaluate the effectiveness of the capstone in term of learning outcomes: Actions that will be implemented to improve the effectiveness of the curriculum in term of learning outcomes:

- We expanded on the instructors' self-evaluation such that more direct assessment of students' learning outcomes is obtained. A set of standards for instructor's self-evaluation will be prepared by the faculty and the Board of Advisors and will be implemented with the annual assessment cycle. The main point of these standards is that the evaluation of students' performance will based on samples of work in three categories of students: those in the upper 75 percentile, those in the 50 – 75 percentile and those below the 50 percentile populations. Thus the assessment results compiled are based on course performances and grades, exams, projects, presentations of students, and writings as required in some courses. Furthermore, each course specifically addresses the learning outcomes and relation between the course and the Program outcomes, the methods used for the evaluation of students' performance and the relevance of the course materials to the Program outcomes following the standards adopted for the assessment process.
- Students will be provided with the course descriptions including learning objectives and outcomes. Students also will provide their input on the Program outcomes. The results from this instrument are used along with those from the instructors' self-assessment of courses as a means to ensuring compatibility in results obtained.
- A more rigorous process in assessing the learning outcomes of this lab course will be implemented, which are in parallel with the Program outcomes. The following outlines process will be used for this capstone course assessment.
    - Individual instructor evaluation of the degree of learning achievement of individual students on a capstone team, which includes consideration of the collective achievements of the team.
    - Peer evaluation (optional by instructor).
    - Grading of deliverables by the instructors.
    - Teamwork survey.
    - Self-assessment.

5. Conclusions:

More often the architecture design is performed by designer separately from the code requirements. However, understanding the appropriate building code can affect the design decisions, save money and even accelerate the process by saving time and efforts. The architecture decisions are related to the code requirements. For example, the building area affect the fire protection systems required and the occupant load affect the egress components widths and number.

This paper described a comprehensive design process that includes both architecture and building code aspects. A comprehensive case study has been presented to demonstrate the feasibility of such method.

6. References:

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