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The Multidisciplinary Approach to Architectural Education: Bridging the Gap between Academic Education and the Complexities of Professional Practice

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Abstract

Many schools of architecture focus on developing student's skills in the spatial and aesthetic aspects of architectural design as a necessary part of their education, however with less effort to inform the students about the nature of actual design in practice. The paper describes the main disciplines that are often involved in the design and construction of actual projects, and highlights the importance of informing architectural students of the complexities of design in practice. It is noteworthy that several activities take place even prior to commencing the design process. These are referred to as pre-design activities that include preparation of a building's program of uses, economic feasibility, site selection, surveying, and geophysical investigation that involve inputs from specialized experts. The paper addresses these activities, as well as the processes involved in design and construction, and concludes with presenting proposals to bridge the gap between education and practice.

Keywords: ARCHITECTURE, EDUCATION, ENGINEERING, BRIDGING, CONSTRUCTION

Introduction

Through my 50-year career I have been teaching at several colleges of architecture while at the same time practicing architecture in nationally recognized firms as well as in my own firm. Most of the employees in my firm over the years have been former students; both graduate and undergraduate. I have also participated in the apprenticeship program under the auspices of the National Council of Architectural Registration Boards (NCARB) which monitors the performance of students and graduate and guides them in preparation for licensing [1]. My teaching, and my particular experience in practice led me to recognize the existing gap between academic education and actual practice, and the need to bridge this gap. Therefore, in recent years I took every opportunity to acquaint my classes with the multitude of activities and disciplines involved in the design and construction of actual projects.

Historically, many masters -such as Michelangelo- were able to perform multiple functions involved in building design. Their knowledge and expertise spanned several fields inherent in design and construction. However, with continuing significant advances in science and technology, and the proliferation of specialized fields with further sub-specializations of knowledge and expertise, it is no longer possible for one individual to effectively emulate the performance of the old masters. Therefore, I point out to my students that the role of the architect at present is in certain ways similar to the role of conductor of a philharmonic orchestra. The conductor does not necessarily need to be skilled in playing any particular musical instrument but must be aware of the various types of musical instruments that comprise the orchestra, their particular ranges of tonality, and most relevantly, control the timing and performance of each musical instrument. I point out, though, that the architect's role is different in one major respect from that of the maestro of the orchestra. Namely, the architect composes 'the music' while conducting. That occurs over a period of months or years during which input from the members of a multi-disciplinary team is sought, and their feedback affects the 'composition'; i.e. the work of architecture.

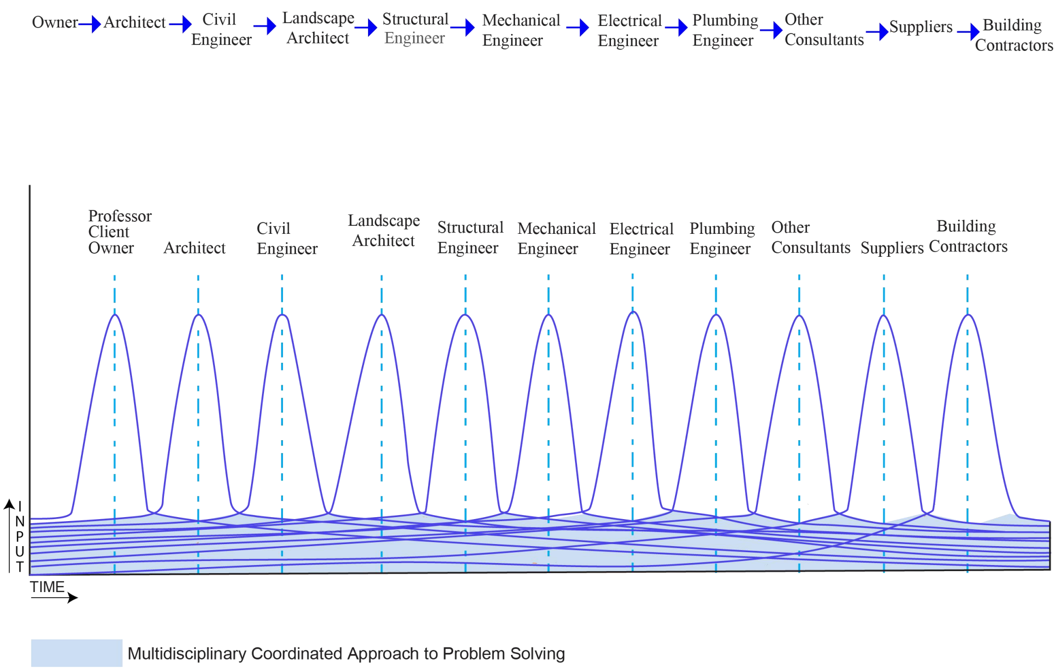

Diagram 1. The Multidisciplinary team coordinated inputs

This paper describes the topics and issues I strive to cover in my class, and often by necessity, am obliged to explain to the young apprentices and employees in my office. I hope that my approach in teaching would provide an example worthy of emulation, and furthermore, that academic curricula be conceived and adopted to better prepare architectural students for future practice.

The paper aims to focus on addressing technical and practical issues relating to education and practice, and, will not cover the promotion efforts that are needed to secure design commissions. Accordingly, the paper will describe the main activities that ensue ***after*** a potential client approaches the architect to provide professional design services. The text covers certain indispensable pre-design activities that are necessary to ensure the practicality of design, as well as the processes commonly involved in the realization of a building project. Generally, I aim to promote a comprehensive holistic approach to architectural education.

Pre-design activities

Clients come from all walks of life and range from an individual to a large corporation. Every client contemplates a set of goals and objectives. However, the extent of preparation for embarking on a construction project varies considerably from one client to another. For example, many clients approach the architect with a well defined program of uses for their prospective project, as for example the components and anticipated area of a private residence, the components and areas in a mixed use commercial/residential project, or the area of an office complex or manufacturing facility. Also, many would have selected a particular site for the project, prepared a budget for construction, and established the feasibility of the contemplated project. Many clients though come less prepared, and the architect needs to be prepared to assist such clients.

Irrespective, a large number of activities by the architect as well as a number of specialized entities and disciplines usually transpires before commencing the design of all types of projects, both large and small. These activities are prerequisite to the successful design and implementation of any given building project. It must be emphasized that proceeding with design without properly addressing the issues involved in any of these activities could lead to major problems down the line and render design activities obsolete or un-implementable. Following is a list of such activities. The order of implementation of these activities and need for the involvement of the architect and the members of the multi-disciplinary team may vary from one project assignment to another depending on the type of client and the nature and the size of the project.

Definition of program and budget

Some clients approach the architect without developing a definitive program or an estimated cost of what they wish to accomplish. Assisting in this respect may be relatively straight forward in the case of a residence but can be considerably more complex for substantial speculative development projects where the architect may be forced to prepare schematic designs, seek input from realtors for market research, and prepare cost estimates for construction often with the help of suitable building contractors, in order to determine the feasibility of the project within an estimated construction budget.

Site selection

Clients who approach an architect to provide design services usually either own, or are committed to purchasing, a particular plot of land for their project. If not, the architect would be called upon to assist in the selection of a suitable site. In such cases the architect would rely on knowledge of the area where they practice, and/or seek the input of a real estate agent to participate in identifying an appropriate site for the project. Paramount in this respect is the review of applicable codes and regulations to establish that the construction of the particular type and magnitude of the contemplated project is allowed. The following site investigations would be relevant in the process of selection.

Site investigations

Invariably, the architect visits the site of the project for visual inspection and documentation of relevant features of both the site and its surrounding context. In addition, the following activities and disciplines are involved in all types of projects.

Land Surveying

The selected project site may have been already surveyed. If not, the architect would assist the owner in commissioning the performance of the survey [2]. At any rate, the survey must be conducted by a licensed surveyor and should indicate the general location of the property, adjacent roads, the property perimeter's dimensions and orientation relative to the North direction, required building set backs from property lines, existing below-grade utilities if any, as well as any easements or restrictions that might affect the use of the property; for example, when the site or portions thereof are prone to flooding. Existing structures if any would be indicated and dimensioned on the survey. Vegetation, and in particular the location of mature trees that may be worthy of preservation would be also shown on the survey drawings. Topography, indicating spot elevation of the land and relevant features, and/or contour lines must be covered and shown on the survey drawings. Obviously, site surveying information has significant impact on conceiving the design of any building project. Therefore, the architect's role in this context is to ensure that site surveying has been properly performed to an extent of detail that is commensurate with the size and requirements of the anticipated project.

Geotechnical investigation

Geotechnical investigation is performed to establish soil characteristics and bearing capacity by drilling boreholes and testing the extracted cores in a laboratory [3]. The information is passed to the structural engineer who uses the data to design the foundations of the anticipated project. One borehole may be sufficient to render the needed information to design the foundations of a small project. However, larger projects on larger sites often involve more intensive investigation that is usually directed by the structural engineer. For example, in the case of tall buildings the structural engineer would specify the depth to which the boreholes should be drilled to establish the potential presence of bedrock, and to obtain information about soil characteristics at various depths. Such information would be used to design structural piles and caps to support the building. The structural engineer also specifies the number and location of the required boreholes in order to discern any variation in the soil strata below grade that could affect structural design.

Environmental assessments and remediation of hazardous conditions

In some cases the contemplated project site may have previously accommodated uses that might have contaminated the soil with toxic agents. In such cases the Environmental Protection Agency (EPA) Codes require the performance of site investigations defined under "Environmental One", and "Environmental Two" [4]. The first type can reveal serious conditions of contamination that necessitate the performance of the second type, which is more intensive. Specialized consultants perform these investigations, and the necessary remedial work of removing, and disposing of contaminants is undertaken by specialized licensed contractors.

The same considerations apply in the cases were a new project entails the demolition or gutting of an existing structure that is suspected of comprising toxic materials such as asbestos, the disturbance of which creates a health hazard. All such cases predicate conducting environmental investigations and assessments that are performed by specialized consultants, and the necessary remedial work to prepare the site for new construction has to be performed by specialized licensed contractors.

In certain cases demolition and remediation work are not performed in the early stages of a project and are delayed and undertaken at the beginning of the construction phase. However, it must be noted that the removal, disposal, and replacement of contaminated soil, and the removal and disposal of hazardous materials from an existing structure are costly operations that impact the feasibility of a contemplated project, and could lead to abandoning a particular site, or cancelling a project all together. Accordingly, it is advisable to consider the cost of the needed work before proceeding with design.

Establishing the availability of utilities infrastructure

Sub-consultants of different disciplines including civil, mechanical, electrical, and plumbing engineering, and landscape architecture are often involved in the pre-design phase to estimate the project's utilities needs, and to establish the availability of adequate infrastructure to support the anticipated demand. This includes water, storm water and sanitary sewer mains and electrical power lines which may be already present in the vicinity of the project site with sufficient capacities to meet the project's needs; such information is often available online. Otherwise, the sub-consultants would investigate the possibilities and cost of extending utilities to service the site of the project. Also, in some cases existing utility lines traverse the site and have to be rerouted. Again, the engineers of the project would investigate possibilities and cost. Such considerations impact the financial feasibility of any given project.

Identification of site features worthy of preservation

The architect may identify existing structures on the site that may be worthy of preservation. Also, the landscape architect could be called upon in certain cases to assess site condition and identify existing features that may be worthy of preservation; such as trees and rock outcroppings. These considerations impact the location of the building components of the project.

Concluding contractual agreements

To ensure smooth progress of the architect's work, it is imperative that there exists a formal agreement for the provision of professional design services with the client prior to commencing the work on a project. This is accomplished by writing a detailed proposal covering particulars of the anticipated project that the architect prepares in consultation with sub-consultants. A typical proposal covers a description of the project's site and program of uses, the scope and duration of the architect's design services, the architect's fees and a schedule for their payment, as well sundry other contractual provisions. Acceptance of the proposal by the owner may serve as a binding agreement to provide professional services for a small project. However, legal forms are more commonly used to affect contractual relations between owner and architect. The American Institute of Architects (AIA) has Standard Forms of Agreement that cover essential contractual relations between Owner and Architect, which are widely used [5]. The forms provide for modification and the addition of addenda or appendices to cover additional special provisions if needed; in which case, legal advice may be required.

If the architect's scope of work is well defined, the architect's fees could be fixed and expressed as a lump sum amount, or a percentage of the construction cost of the project. If the scope of work cannot be ascertained beforehand, compensation is stipulated on a time and material basis. In this case the architect would provide hourly rates for various categories of professional and employee inputs, both for the architect and the sub-consultants, and indicate the categories, and method of compensation for project related expenses. Also, in some cases certain aspects of the scope of work can be defined while others cannot. In such cases the financial compensation of the architect would be prescribed both as a fixed fee, as well as on a time and material basis.

Clearly, members of the architects' team need to be involved at this early stage, to define their scope of work and fee requirements, and to conclude formal agreements with the architect for the performance of their respective services; the American Institute of Architects provides a standard form for such agreements [6]. This entails familiarization with the scope and particulars of the contemplated project, and often triggers feedback from the members of the team that affects the architect's overall approach to addressing the project.

Obtaining insurance coverage

It is recommended, and often mandated by some clients that the architect obtains both professional liability and workers' compensation insurance covering each particular project and indicating the limits of insurance coverage in each case.

The phases and the main entities involved in the processes of design and construction

The processes of design and construction generally unfold in well defined phases: a) schematic design, b) design development, c) preparation of Construction Documents, d) bidding, selection of building contractors, and award of the Construction Contract, and e) Construction and Administration of the Construction Contract. The main entities involved in these phases are: 1) the client/owner, 2) the architect, 3) governing authorities, 4) a host of specialized consultants, often referred to as the architect’s multidisciplinary team, 5) numerous suppliers of building materials, equipment, and systems, and 6) building contractors. "Table 1" below lists the phases of design and construction, and indicates the main entities involved in these phases.

Table 1.

Phase: Entity	a) Schem.	b) DD	c) CD.s	d) Bid	e) Constr.
1. Client/Owner	X	X	X	X	X
2. Architect	X	X	X	X	X
3. Governing Authorities	X	X	X	X	X
4. Specialized consultants	X	X	X	X	X
5. Suppliers	X	X	X	X	X
6. Building contractors	X	X	X	X	X

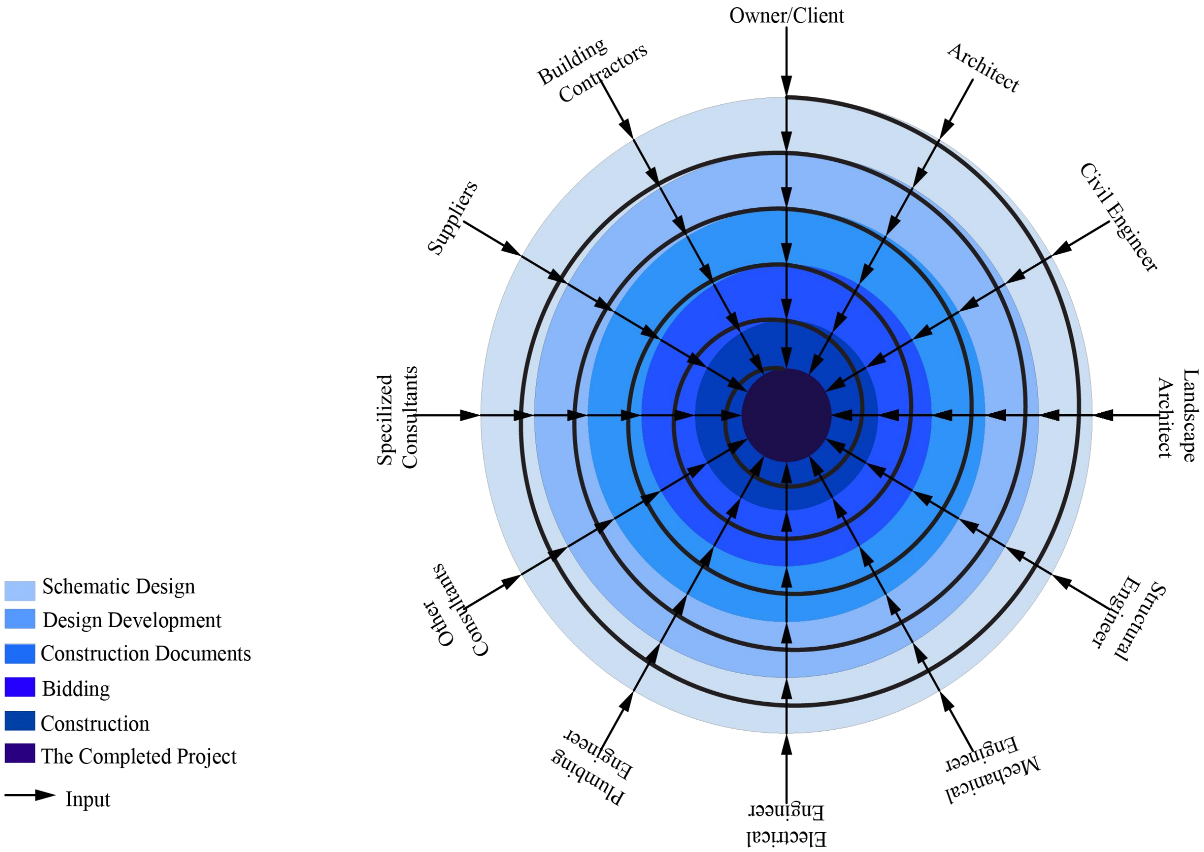

Diagram 2. The entities and disciplines involved in the realization of a building project interact through different phases in a continuous process that culminates in the completed project.

Following is a concise description of the respective roles and inputs of the main entities during the phases of design and construction.

The owner's role

The owners are the initiators of the design and construction processes. They remain constantly and intimately involved throughout the different phases of these processes. All along, based on the architect's advice, the owner makes vital decisions that affect the progress of the work in a timely manner. They also compensate the architect and the members of the design team for performing their professional design services and pay for the construction of the project.

During the design phases, the owner reviews and comments on the architect's work regarding both the practical and aesthetic aspects of design, and interacts with the architect to reach mutually acceptable design solutions which are formally approved at the end of each design phase.

The owner, in consultation with the architect, selects the type of Construction Contract to be adopted for the realization of the project; for example, a lump sum, a percentage of construction cost, or a cost-plus fee type of contract [7]. The owner participates with the architect in the process of bidding, analysis of bids, selecting building contractors, and awarding the Construction Contract to the successful bidder.

During construction, the architect inspects and comments on the completed portions of construction, and in consultation with the owner, accepts or rejects the work, issues or authorizes change orders to modify aspects of the work, process payments to contractors, and ultimately formally accepts the completed building project.

The architect's role

The architect is the designated legal leader of all the activities involved in design and construction. The architect establishes the need for the involvement of various disciplines and entities and selects the members of the multidisciplinary team who would participate in all the phases of the realization of the project. The architect prepares appropriate design drawings during the design phases and distribute the drawings to all involved who use them to prepare their respective design inputs. The architect is involved in the selection of construction contractors and the administration of construction activities that include communication with all those involved in the project. It should be noted that all formal project communication either by the owner, or any member of the design and contraction teams must be funnelled through the architect. Following is a brief account of the architect's role in each phase of the realization of the project.

Schematic design

The architect initiates the design process through schematic design, which is the first attempt to conceive a spatial solution to organize a given program of uses in a coherent manner. Schematic design often involves the preparation of alternative solutions and presentation materials, communicating with the client to establish his preferences, and modifying design as needed to obtain the client's approval. In that way it is similar to design at a school of architecture; albeit, instead of getting comments on design from a professor in studio, the comments come from a client, whose views and preferences are usually more binding. The similarity ends here however, since schematic design in practice is conceived in collaboration with a multi-disciplinary team of experts, while at school, schematic design is conceived without the benefits of such collaboration. It is also noteworthy in this context that the following phases of the design process in practice are rarely undertaken in schools of architecture.

Design development

The design development phase involves detailed consideration and selection of the main components of a building project. The work involves the architect in participation with his team of experts, as well as numerous types of suppliers and manufactures of building materials and equipment whose products may be contemplated for use in the project.

The preparation of Construction Documents

The capitalization of the designation of these documents is due to their legal significance. They are intended to cover every aspect of the activities involved in the construction of a building project to ensure proper and expeditious execution of all aspects of the work. Their volume and content are directly related to the size and complexity of the project. As in all the preceding phases, the architect conducts the process of the preparation of the Construction Documents in collaboration with a host of participants.

The Construction Documents are comprised of drawings and specifications. The drawings cover all the disciplines involved in design, and describe the building and its components in a graphical format; including site plans, building plans, elevations, and sections, as well as wall sections and details covering the various elements of the building. Specifications describe the materials and methods to be used in construction in written format. In smaller projects, outline specifications are often indicated on the drawings. Larger projects require the preparation of separate and elaborate documents of specification. The completed Construction Documents (CDs) are submitted to local authorities as part of the application for a Building Permit. Invariably, authorities review and comment requiring certain modifications of the documents, which entails revising and resubmitting them. Final approval by the governing authorities leads to issuing a Building Permit, and signifies the end of the design phases of the project.

Bidding and selection of building contractors

Construction can be approached in different ways. The owner may be himself a builder who proceeds directly with construction after securing a building permit. In some cases the architect is prepared to assume the responsibly for construction by performing the role of construction manager and relying on subcontractors to execute the work. Also, the architect and/or the owner may have a favourite building contractor that they directly entrust with the execution of the work. However, following is the common practice in awarding construction contracts.

The architect and the owner decide on the method of awarding the Construction Contract. In most cases, the architect in consultation with the owner prepares a list of suitable building general contractors and invites them to submit bids for the project. Another method referred to as open bidding, relies on advertising in suitable media to solicit bidding from interested general building contractors. In all cases, invited or interested contractors are provided with copies of the Construction Documents to prepare their bids. The submitted bids are analysed to assess their adequacy and to evaluate and compare financial offers. Usually, the Construction Contract is awarded to the lowest bidder. It is noteworthy that in common practice the selected contractor would not be known beforehand, and thus is not likely to have participated in the design phases of the project. However, it is advisable to invite building contractors to participate during the design phases to provide construction cost information, or advice based on their experience with similar projects as indicated on "Table 1".

Construction

The architect periodically visits the construction site to establish the extent and the adequacy of the completed work, and to ascertain that the work is being performed on schedule. The architect identity's and documents deficiencies and instructs the contractor to correct defective work. The architect also assesses and processes any change orders requested by the owner and the contractor, the contractor's technical shop drawings and financial submissions, and advises the owner to take appropriate action. The architect continues to perform these functions until the final completion of construction, release of liens from subcontractors, acceptance by local authorities' inspectors, issuance of a Certificate of Occupancy, and the release of the contractors' final payment by the owner.

The involvement of governing authorities, codes and regulations

Codes and regulations are involved in all the phases of design and construction, and impact professional design by various disciplines [8]. They often prescribe the allowable area and permissible height of a contemplated building, onsite parking requirements for different building uses, the size and location of means of egress from the building, handicapped accessibility provisions [9], as well as sundry other requirements that directly affect schematic design. Codes also affect decisions during design development and preparation of construction documents in numerous ways; for example, since they prescribe the fire resistance rating of various structural systems and building components, and the requirements for fire fighting systems and equipment. Furthermore, construction documents must be submitted for approval to the concerned authorities in order to obtain a Building Permit; this entails their review and comment which often involves modification of the documents. Governing authorities also approve the competence of many types of contractors to perform various aspects of construction. At the completion of construction they inspect the building project, indicate items that must be corrected, if any, and ultimately issue a Certificate of Occupancy that allows the use of the project.

The role of specialized consultants

The members of the architect's multidisciplinary team participate in all the phases of a building project. Their various specialized inputs are described in the following "Section 4".

The input of suppliers of building materials, equipment, and systems

The number and variety of such suppliers cannot be comprehensively identified. It suffices to indicate that they cover every conceivable component of a building project, including all sorts of building materials and finishes, equipment such as elevators, and systems to provide renewable electrical power. They usually participate in all the phases of design by providing detailed information about their products that is integrated in schematic design, design development, and the preparation of construction documents. Those whose products are selected, participate in the construction of the project. Also, with the advent of sustainable design, building materials and equipment manufacturers provide information about the sources of the raw materials used in their products as well as the possibilities of recycling the products. This information is used in life cycle analyses and establishing sustainability.

The role of building contractors

The role of building contractors is to construct the project as described in the Construction Documents. Commonly, the work is undertaken by a general contractor (GC) with a team of subcontractors. The GC's role with subcontractors is similar to the architect's role with professional sub-consultants. Subcontractors are usually specialized in performing different aspects of the work, and their areas of specialization generally mirror those of the different sub-consultants of the project.

The GC prepares an elaborate schedule of construction indicating the timing and duration of construction activities to be approved by the owner and architect. The GC ensures the timely delivery of needed materials and equipment to the construction site, as well as the timely performance of the subcontractors to meet the schedule. Thus, the GC is the 'conductor' of construction activities.

4. The members of the multidisciplinary team and their particular inputs

Table 2" below lists the consultants that usually comprise the multidisciplinary team that collaborates with the architect, and indicates their involvement in the different phases of design and construction.

Table 2.

Consultant / Phase:	a) Schem.	b) DD	c) CD.s	d) Bid	e) Constr.
4.1. Civil engineer	X	X	X	X	X
4.2. Landscape architect	X	X	X	X	X
4.3. Structural engineer	X	X	X	X	X
4.4. Mechanical engineer	X	X	X	X	X
4.5. Electrical engineer	X	X	X	X	X
4.6. Plumbing engineer	X	X	X	X	X
4.7. Other consultants	X	X	X	X	X

The consultants are intimately involved in all phases of the work. They constantly communicate with the architect and provide appropriate input relating to their particular fields of expertise in each phase. Their input in selecting the various systems and components that will be incorporated in the project directly impact the preparation of schematic design. They provide more detailed designs during design development, and are responsible for the preparation of their respective sections of the drawings and specifications that are comprised in the construction documents. It must be noted that their respective inputs are invariably covered by particular codes and regulations, and that they are responsible for meeting these requirements. Each is licensed to practice in his particular field of expertise and is required to affix his professional seal to the construction documents. The consultants in their respective fields of expertise continue to participate in assessing the adequacy of contractors' bids and the administration of the construction contract. Following is a brief description of the particular inputs of various consultants in the processes of design.

Civil engineer

The civil engineer establishes the availability of adequate infrastructure utilities to support the project, and designs the connections from water, storm water, and sanitary sewer mains to service the site of the project. Another main input covers storm water management on site. The civil engineer calculates the volume of runoff from impermeable surfaces, and participates in establishing grade and building elevations to ensure the proper flow and discharge of storm water. This often predicates the provision of storm water detention, and/or retention areas on site, and the civil engineer calculates their capacities and designs the facilities as required by governing codes and regulations.

Landscape architect

It is noteworthy that the involvement of the landscape architect is often delayed to the last stages of the design process; to add icing to the cake, so to speak. However, the landscape architect should be called upon at the early stages of design to assess site condition and identify existing features that may be worthy of preservation such as trees and rock outcroppings, and to contribute in identifying the location of the building components of the project. The landscape architect prepares the landscape component of schematic design on grade, and on the roofs of buildings which is now common, and selects the appropriate plants to be used on site, as well as off site, as is often required by code. Also the landscape architect estimates the needs for plant irrigation which add to the overall water demand for the project. During the design development and the construction documents phases the landscape architect develops design in more detail covering methods of planting, the design of plant irrigation systems, and the details of the hard landscape elements of design.

Structural engineer

The structural engineer assists the architect in selecting the appropriate structural systems for the project as for example wood, masonry, steel, concrete, or combinations thereof. The structural engineer calculates the loads of the building components and designs the structural elements such as walls, columns, and beams and floors that transfer the building loads from the roof down to the foundations of the building which the structural engineer designs based on the nature and bearing capacity of ground conditions. The structural engineer also makes provisions in the structural design to sustain wind forces, and in seismic prone areas to withstand and mitigate earth tremors.

Mechanical engineer

The mechanical engineer is mainly concerned with the design of heating, ventilation, and air conditioning systems (HVAC) in a manner that provides comfortable conditions for the users of the project. These include different types of equipment and components of various sizes and space requirements, the accommodation of which impacts the overall design of the project. The equipment includes condensing units and in some cases cooling towers that could be located on grade or on the roof of a building, as well as heating and air handling equipment, ducts, and vents to discharge and recycle air which are often accommodated within the building. Thus, the mechanical engineer works closely with the architect to select the appropriate HVAC systems and equipment that are needed to serve the particular uses of the project, to design these systems, and coordinates with the architect to provide adequate space to accommodate mechanical equipment and to thread the elements of air distribution and circulation through the fabric of the structure. Also, since HVAC equipment is run by electricity, the mechanical engineer provides the electrical engineer with the HVAC system's power requirements, and in the cases where cooling towers are used, water consumption is coordinated with the plumbing and civil engineers.

Electrical engineer

At the early stages of a project, the electrical engineer, based on previous experience, estimates the power consumption needs of the anticipated project, and establishes the availability of electrical power from the existing power grid in proximity of the project site. The electrical engineer investigates the possibilities for providing electricity from renewable sources such as geothermal, solar, and wind power. The electrical engineer's input in this respect impacts the viability of the project.

During the design phases, in coordination with the architect, the electrical engineer designs both interior and exterior lighting systems, locates power receptacles inside and outside the building, and identifies the power and voltage requirements of sundry project components such as mechanical and plumbing equipment, elevators and appliances. Based on this, the electrical engineers calculates the needs for both connected and anticipated electrical power consumption, designs the cable connections to the source of electrical power, and the panels and distribution systems of electricity to all the points where it is required. The electrical engineer also designs the telecommunication systems of the project in coordination with the architect, and ensures that adequate space is provided to accommodate electrical and telecommunication panels and equipment. In addition, as is often the case in many projects, the electrical engineer identifies and calculates the needs for standby power generation to supply elevators, exit signs, and fire protection pumps for example. In such cases the electrical engineer selects appropriate standby power generation equipment, and designs the electrical distribution systems to provide power as required by codes and regulations.

Plumbing engineer

In the early stages of a project, the plumbing engineer participates in establishing the availability of water and sewerage mains to meet the needs of the anticipated project. During the design phases, they are mainly concerned with the design of the systems that provide and distribute potable water for use in the project both for domestic uses and fire fighting purposes, as well as the systems that collect and dispose of soiled fluids. The plumbing engineer ensures that the water supply is provided under sufficient pressure to serve the highest point where water is needed in the project, or otherwise designs systems to pump and store water to higher levels and allow water to fall by gravity to serve the needs of the project. The plumbing engineer participates with the architect and the client in selecting plumbing fixtures and equipment, indicates the space needed to accommodate equipment, and water supply and drainage pipes, and collaborates with the architect in integrating the elements of the plumbing design in the fabric of the structure.

Other consultants

In addition to the main fields of expertise discussed above, numerous other specialized consultants are often involved in the realization of most building projects. Their numbers and fields of expertise relate to the type and size of each particular project. They include, but are not limited to, interior designers, lighting, acoustics, IT, and kitchen design consultants, who are usually involved in a large variety of projects, such as office and residential buildings, hospitals, libraries, schools, theatres, auditoria, event venues, and restaurants. Additional disciplines are often involved in various types of building projects. For example, some industrial projects require the involvement of specialized fire fighting consultants to design water sprinkler systems, and other sophisticated fire suppression chemical systems such as halogen that are tailored to contain particular hazardous conditions. Also, specialized cost estimators and specification writers are often involved in many larger projects.

Discussion

The above discourse illustrates the complexity of the processes involved in the realization of building projects in practice. It is intended to highlight this fact to the benefit of the young students of architecture, who often graduate with little knowledge of what awaits them in practice.

The educational approaches of different schools of architecture have one major basic tenet in common. Namely, that the main skills of architects that differentiate them from other professionals relate to their prowess at spatial composition. Accordingly, most curricula focus on developing this ability by engaging students in basic design studios in the first year or two of their education, followed by engaging them in schematic design assignments of various types of building projects for three years until graduation. The curricula of different schools of architecture however vary considerably in the extent to which they prepare their students for practice.

Two schools of thought prevail in this context. On the one hand, some maintain that encumbering students with a load of information relating to the complexity of practice will tend to curtail their freedom and inhibit their abilities to conceive original and iconic design solutions. The schools that adopt this position tend to curtail the coverage of vital practical information in their curricula. On the other hand, many schools realise the importance of preparing their students for future practice. The extent of coverage of practical issues, however, varies considerably from one school to another. The challenge, therefore, is to find the optimum balance between the various different approaches to architectural education that would be of benefit to both the students, as well as their future employers.

6. Conclusion/The multidisciplinary approach to architectural education

Based on the above discussion, I propose the following action to be considered by universities and colleges of architecture.

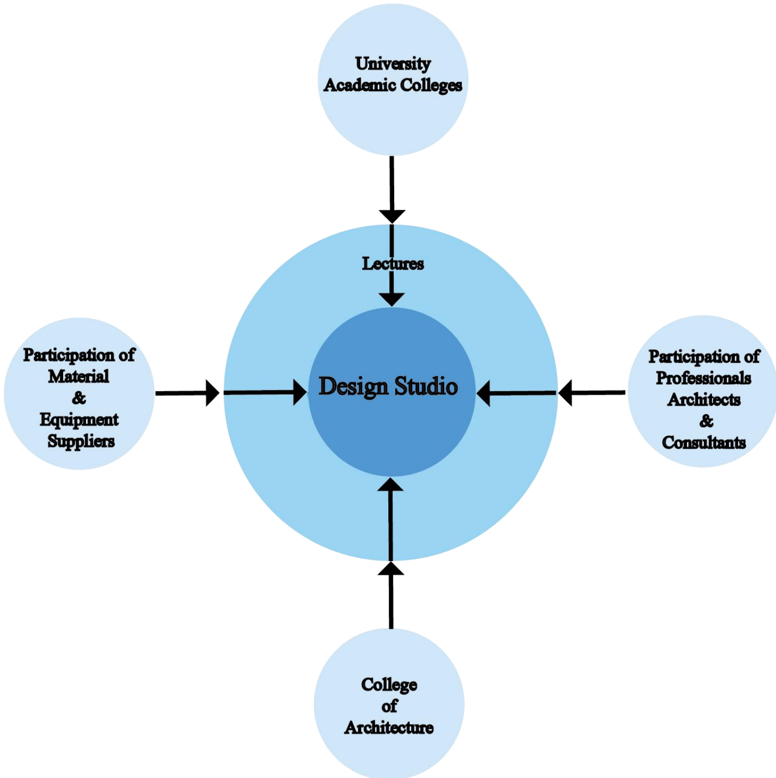

Diagram 3. The Multidisciplinary approach to architectural education

1. Universities: Most universities have a stable of experts under one roof that cover socioeconomics, planning, engineering, and sundry other relevant disciplines. They could work together to form multi-disciplinary teams that are similar to those usually involved in the processes of architectural design in practice, and thus provide needed input to colleges of architecture. Also, research and development programs could be established within universities to take advantage of the available wealth of knowledge and expertise in addressing topics of interest to schools of architecture as well as other colleges. The University of Houston has a myriad of such Centers [10]. However, universities have set degree programs for their various colleges, and funding structures that tend to hamper

academic cooperation and cross-pollination between the colleges. Universities need to develop flexible policies that allow for multi-disciplinary education across their colleges. This is particularly important for Tier 1 universities seeking research grants. The advantage lies in allowing professors, students, and support staff from different colleges to engage in a dynamic and integrated approach to higher education.

2. Colleges of Architecture: The following particular steps are recommended for implementation within the college realm.

- Currently, most curricula are divided into design studios (on average six credit hours) and support lecture classes (two to three credit hours). The studios and lectures function separately, and the lack of coordination often leads to the students being unable to integrate the knowledge they gain in lectures into their design studio projects. This can be solved by inviting lecturers to visit the studio as members of the College's multi-disciplinary team to provide real time input to the students' projects.
- One of the challenges for many students is making the transition from first and second year ***basic design*** studios to third and fourth year ***architectural design*** studios. The latter studios include program and site specific assignments. In an effort to ease and effect an orderly transition from basic design to practical architectural design, the process needs be initiated by introducing simple project assignments, progressing to more complex ones, and engaging students in design development and the preparation of construction documents in latter years. Also, third, fourth and fifth year studio instructors are encouraged to introduce well-researched building programs and carefully selected actual site locations for the student's assignments. This would foster and encourage responsible architectural design, and better prepare the students for future practice.
- Create a design build studio where students are able to participate in the construction of small projects.
- Involve the students in community services projects. This leads the students to recognize the value of their work to the community, and thus, has proven to heighten the students' interests in their work. This approach has been successfully implemented at my college [11].
- Create research departments within the college of architecture to engage the students in multidisciplinary research projects. This broadens the students' horizons, and heightens their interest in their work. Research projects could also be a source of funding for the

college that could be used towards publication and awarding scholarships. Our collage created the Center of Sustainability and Resilience (CeSAR) for these purposes [12]

- Students of architecture should work with industrial design/fabrication, interior design, landscape architecture, urban design, and urban planning students in a multi-disciplinary team within the college. This would broaden their knowledge, and prepare them for interacting with different disciplines in future practice.
- Facilitate and encourage apprenticeship with architectural firms.
- Encourage the students to participate in architectural competitions that require a multidisciplinary design approach such as the Annual ULI Gerald D. Hines competition[13].
- Encourage the students to participate in international architectural exhibitions such as the Biennale in Venice; I am proud that our college's submission was awarded the Global Arts Affairs Foundation Prize in the 2014 Architecture Biennale [14].
- To broaden the students' cultural horizons, organize study abroad programs and encourage students to participate, and facilitate the acceptance of foreign students in the college.
- College Advisory Board: Colleges of architecture should encourage local community leaders to participate as members of an Advisory Board to the college. This will coordinate the college's goals and objectives with those of the community. This can also generate an additional source of income to the college

3. Practicing Professional Architects and Consultants: Colleges of architecture need to encourage the participation of practicing professional architects, engineers, and consultants of different disciplines to join in guest lectures as well as provide input in design studios. From practical experience, I have found that professionals enjoy interacting with the students and the students benefit enormously from exposure to the experts.

4. Materials and equipment Suppliers: Colleges of architecture need to invite industry representatives to make presentations of their products and systems, and to provide studio input as appropriate. Knowledge of common and state-of-the-art building materials and equipment is an essential part of the students' comprehension of the complexities of architectural design, and exposure to the latest construction techniques, innovative materials and products is invaluable in their preparation for professional practice. In an effort to make such information available to the students, we created within our college the "Materials Research Collaborative" (MRC) as a handy resource for material discovery [15]. The MRC

compiles a data base of materials including those made in Houston and Texas, as well as reuse considerations.

Adoption of the above proposals would facilitate accreditation, reduce the number of years required for apprenticeship, and prepare the students to enter the work place.

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