Structures and Studio: Re-integration of Art and Science

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EXCLUSIVITY AND INTEGRATION

To be able to incorporation and develop structural thinking within the context of design thinking developed through studio instruction is considered a requirement for comprehensive design. The difficulty accomplishing this result can be attributed to the desire to categorize these areas of thinking as exclusive to Science and Art; Science - from the predominance of structural principles and laws of behavior, and Art – from the predominately creative manifestation of tangible spaces that meet more needs than just functionality and stability. These categorizations can easily be mistranslated to the exclusive professions of Engineering and Architecture.

RE-INTEGRATION

As a member of the profession of engineering teaching within architectural education, I have frequently been called upon to play the role of "consultant" to student design projects. On one such occasion, I was informed that my consultation was intended to encourage the students to develop a "realistic" structure that they could show as definite member sizes in their drawings. After reviewing several student projects and identifying the areas of the structural idea needing attention, I was informed by my colleague that there were only two types of structural engineering consultants. The first was the type who would disagree with the designer's structural configuration because of complexity or cost leading to a "ridiculous" argument. The other was able to provide useful *feedback* to the designer on the structural proposal in one consultation.

This sentiment illustrates the common belief and lesson imparted to students that the role of structure in design is exclusive, and that marginal integration must be tolerated. This ideology is manifested by the frustration of students to desire structures and technology to be "black and white", and to feel uncomfortable when it is not.

STATUS QUO

The historic evolution of the collaboration of disciplines - this transition of structural consultant as design team member to mere technician - is eloquently described by Angus Macdonald in the last discussion of his text Structure & Architecture [1]. He defines the collaboration from the time of the master builder, or closest collaboration of design members, as the period of *structure respected*. *Structure accepted* is applied to the architecture up to the Modern period where interest was not focused on structure. The source of this shift is attributed to the change in the role of structural elements to primarily visual ones and the mastering of construction technologies. What is most disturbing is the classification of the collaboration type in the 20^{th} century as *structure ignored,* relegating the non-designers to role of support technicians. Macdonald does, however, see a future in a third "type" of structural consultant – the one who is both the architect and engineer such as Pier Luigi Nervi and Santiago Calatrava.

The architecture produced by these engineer/architects, and the collaborative teams of designers, engineers and constructors is recognized to be at the leading edge of good design. Team members that can communicate as well as influence the design formulation will be those who do not feel the need to be exclusive with their design contribution and will be in demand by employers as well as clients. But requiring rigorous education and training in both professions is not practical or realistic for most students that have the desire to create our built environment.

EMBODIMENT

The fact that there are professionals who can think with science and art in mind suggests that there are parallels within the planning process through completion, and consideration of all necessary building functions. Also, the use of experimental studios to examine sculptural interpretation of structural form and structural interpretation of surface structure theory [2], and the abundance of creative tools to visualize structure learning is evidence of the need for integration [3][4]. Unfortunately, there is no straight progression from tool or theory to mastery of design.

One approach to defining the similarities in the development of design proficiency is to examine the levels of critical thinking and knowledge accumulated in the education of both professions. If a student comfortable with the variations and iterations of design can draw on parallel processes in structural formation, re-integration will be effected.

THINKING ARCHITECTURE

The National Architectural Accrediting Board has set Criteria #29 of the Student Performance Criteria as the "ability to produce an architectural project informed by a comprehensive program, from schematic design through the detailed development of programmatic spaces, structural and environmental systems, life-safety provisions, wall sections and building assemblies, as may be appropriate; and to assess the completed project with respect to the program's design criteria [5]"

In order to develop this ability, the common emphasis in an undergraduate or graduate curriculum is to order coursework along the lines of Bloom's Taxonomy which shows the increasing levels of complexity of thinking (Table 1) [6]. At the introductory level we wish to impart knowledge. For example: the student is presented with a noteworthy architectural structure and should be able to recite facts and dates about it. The vernacular of architecture is learned. At this level the student should be able to demonstrate that they can speak and write *knowingly* on subject matter contained in the professional curriculum, partially fulfilling criteria #1 of Verbal and Writing Skills.

Beginning with design instruction in studio, the student moves both into the comprehension and application levels of thinking. Here they must be able to interpret what the program means and explain their ideas, and defend them. They must apply rules, methods, concepts, principles, laws and theories. They must be able to translate the critique from their instructor and jurors of how they applied those laws and theories to their designs in order to solve new problems. This is the stage the where they develop confidence in their ideas.

Table 1 –*Bloom's Taxonomy: Levels of Thinking [6]*

Level	Involves
Knowledge	facts, concepts
Comprehension	translation, interpretation, demonstration
Application	application of rules & methods
Analysis	decomposition & organization recognition
Synthesis	analysis & organization
Evaluation	evaluation & judgment

With upper level studio experience the student should be thinking at the levels of analysis and synthesis. Here the student must understand the various parts of what they are studying, in this case architecture, and see the parts as separate entities. They should be doing something new and different with the learned information, and communicating their ideas in original and creative ways. They should be organizing, modifying, rearranging and revising on their own.

The last level of Bloom's Taxonomy is evaluation. The student thinking at this level has the ability to make judgments based on evidence and determine the value of that material based on definite criteria. This *parallels* the statement in criteria #29 that the student should be able "to assess the completed project with respect to the program's design criteria." In terms of student goals and how they behave at this level, they should be appraising, comparing, contrasting, interpreting and justifying the value of purposes, ideas and methods, and the accuracy of materials and ideas.

The correlation of the levels of thinking to the technical subjects in the curriculum is also worth examination. The basic knowledge level and vocabulary of terms such as"*beam, column, loads,"*and *forces* has been attained by the student prior to enrollment in a dedicated lecture course, preferably in coursework in introductory design and physics. The relationship of the basic structural elements to the shape and performance of a structure is at the next level in the Taxonomy; that of comprehension. The practice and development of this level of structural thinking in studio can be seen in the construction of physical models in studio, although modeling materials lacks the proper weight to scale proportions to effectively show full scale structural behavior.

It is at the level of application in the Taxonomy that the technical subjects require thinking from undergraduate as well as graduate students. They must be able to apply what has been learned to another situation while computing, solving and using rules and methods. This appears to be challenging to students who have an aversion to calculations, but it also is a great difficulty to students who have trouble seeing similarities in application when the structures being analyzed *look* different. Students prefer limits or bounds to the technical solutions, while they easily accept that the variety of creative design solutions is relatively unbounded.

Even those students who are successful at analysis have difficulty with the level of synthesis. The primary behavioral terms for this level of thinking include creating, devising, designing, planning and revising. A typical example of synthesis is in the design of a beam. The student must be able to identify the conditions of the beam with respect to its location in a structure, how it is connected, what area it must support, and the minimum required loading. They must be able to determine the applicable stress limitation with respect to design methodologies specific to the chosen material in order to select a preliminary section size. They must be able to evaluate the chosen section with respect to other stresses, and particularly with respect to deflection and deformation. The application of accumulated knowledge to structural design can be quite overwhelming to a student at this point.

In addition to the process of design, evaluation is also required of their work which typically involves comparing and interpreting the outcome of the design. In the beam design example, the final evaluation involves comparing the stress values and deflection values to prescribed limits and revising if necessary. This can also be very challenging to a student of architecture. One reason may be that the sense that the solution “feels” right is much harder to trust than a visual assemblage that can be sensed to “look” right.

THINKING ENGINEERING

To understand how programs educating and assessing technical students evaluate their graduates, Criterion 3. Program Outcomes and Assessment of the Criteria for Accrediting Engineering programs can be examined [7]. There are only 11 criteria that apply to all subject areas in engineering, with specific curriculum criteria for the individual subjects. The criterion that most closely resemble Criteria #29 are (c) *an ability to design a system, component, or process to meet desired needs* and (e) *an ability to identify, formulate, and solve engineering problems*. More specifically, the program criteria for Architectural and Similarly Named Engineering Programs requires that design has been integrated across the breadth of the program, in addition to specific knowledge areas:

Criterion 3. Program Outcomes and Assessment

Engineering programs must demonstrate that their graduates have:

(a) an ability to apply knowledge of mathematics, science, and engineering
(b) an ability to design and conduct experiments, as well as to analyze and interpret data
(c) an ability to design a system, component, or process to meet desired needs
(d) an ability to function on multi-disciplinary teams
(e) an ability to identify, formulate, and solve engineering problems
(f) an understanding of professional and ethical responsibility
(g) an ability to communicate effectively
(h) the broad education necessary to understand the impact of engineering solutions in a global and societal context
(i) a recognition of the need for, and an ability to engage in life-long learning
(j) a knowledge of contemporary issues
(k) an ability to use the techniques skills, and modern engineering tools necessary for engineering practice.

—Excerpt from the ABET Criteria for Accrediting Engineering Programs [7]

Engineering educators have been dealing with the challenge of integration across a breadth and depth of knowledge by examining how that integration occurs in practice and what specifically aids the development of the hierarchy of thinking. The approaches have focused on case models; "studio" methods, team work or what is more generally termed as cooperative learning. The methods don't radically replace classroom based learning, but practically effect closure in the gap between theory and practice. The benefits of cooperation for students are positive interdependence, face-to-face promotive interaction, individual and group accountability, interpersonal and small group skills, and group processing [8], qualities represented by collaborative architectural design teams.

It seems ironical that architectural studio-based learning has been the model for improving the assessment outcome of engineering education. Kuhn [9] sees the attraction of the studio education as being able to blend the functional and the structural with the social and the technical, with the social aspect being something engineers are too commonly accused of neglecting. The advantages of the methodology, when applied to software design, includes the use of the complex, open-ended, semester-long projects, the rapid prototyping and evolution of design solutions, the frequent formal & informal critique from multiple sources, study of precedents, and use of a variety of media. The application of studio-based instruction to engineering learning resulted in the conclusion that the instructor had to assume the role of coach successfully while dealing with team dynamics and selecting and training student leaders. This can be a difficult transition for instructors experienced with the traditional classroom lecture learning environment.

EXPRESSION

Successful application of peer-based learning in engineering produces interdependence between group members, individual accountability, and group processing of learning among other things [10]. The notable difference between architectural studio learning and engineering is the direct emphasis on peer and team interaction. Complex problems of wide scope are attacked by teams rather than individuals with identical agendas. What is most interesting is that student sense of accomplishment does not diminish noticeably from that found with independent design, but it increases higher level thinking skills.

The desired outcome from studio performance is a successful design review presenting conceptual focus and application on program, presentation graphics & details. The level of thoroughness can be hindered by either conceptual development or application.

"Coaching" of individual effort by design faculty attempts to promote forward progress and reassessment of student work. Issues with technical aspects can appear to be more challenging to address for both faculty and student when the main focus on progress has been elsewhere. Modification of the design due to technical challenges can be considered to be extremely painful and distasteful at this stage, and an aversion to integration is likely. An illustration of this view was published in a student periodical as a possible answer in a review: "[T]alk about how much you wanted to really investigate how the structure of your impossible building was supposed to work, but your studio prof wouldn't let you"" [11]. Comprehensive design with this bias will not be easily obtained.

Vertical studio environments have the same intent of cooperative learning without the constriction of students at various levels working on the same projects. The intent is that the junior students experience and possibly interact with senior students who are comprehensively designing. Various levels of success have been achieved with respect to the level of formal interdependence and face-to-face interaction, how comfortable the faculty is being a coach, and how resistant the students are to change. Development of critical thinking skills related to design has also been promoted through the use of practical argument based on rhetoric [12].

Any aspect of promoting higher level thinking will result in skills that clients, employer and instructors find valuable if there is sufficient written, visual and oral communication to effect it. Employers expect a new employee to experience a learning curve, but need to see drive and leadership in the process. This is evident when a young designer, given a task that they are unfamiliar with, takes the initiative to seek help or to do the research from self-motivation by applying analysis, synthesis, and evaluation. Providing positive cooperative learning environments enables students to trust their skills and evaluation methods in order to show this drive.

STRUCTURES & STUDIO

The development of higher levels of thinking is critical to successful demonstration of comprehensive design as well as to the evaluation and implementation of technology within those designs. Fostering the environment and providing the experiential learning should not be categorized into studio or classroom setting, but must be consistently provided across all design areas. Considering Criteria #29 to be a separate item, rather than the overall goal to which all other Criteria are subjected, perpetuates the segregation of technical subjects from design.

Informally fostering the cooperative learning environment by consulting, directing and assistant "coaching" is one method to incorporate technology into studio design, as is providing mini-lectures on technical material the design students are researching. Case studies and evaluations are also useful especially when incorporated in team projects. But much more can be done by identifying the thinking desired and orienting the projects, exercises, or designs along actions required of higher level thinking.

Input by students on fostering a similar feel to design studio with examination of precedents is common, but unfortunately it comes with the condition that calculations must be abandoned. Promotion of the same culture within all design aspects would foster Criteria #29 and re-integrate and art and science that are not exclusive for design.

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