One of the toughest challenges facing educators of building technology is its successful integration into a broader architecture curriculum. How can discussions of building technology be concentrated enough to allow for the necessary focus on critical technical issues, while avoiding technology’s isolation from other architectural issues? This presentation addresses how two faculty members at Cal Poly are attempting to answer this question with four new courses that are integrated horizontally, vertically and progressively within the curriculum.

Central to our efforts is a shared interest in the merging of design and making. In the best work there is no separation between design and construction; rather they inform each other. The process of making buildings is an interactive continuum among several disciplinary strands on which every architectural curriculum is based. To define them separately denies a holistic approach to the creation of a building, whether in academia or the real world. It is our interest and goal to contribute to an inter-strand or interdisciplinary environment which mirrors the multi-faceted nature of the architectural profession.

1.0 Observations

We arrived at Cal Poly at the same time with the same mission: to rethink the building technology courses (traditionally referred to at Cal Poly as Practice) with an eye toward better integration of technology topics in design studio work. At Cal Poly, Practice classes address a spectrum of technology topics. These topics include sustainability, building technology, materiality, the history and theory of technology and building processes. With fresh eyes we examined the entire curriculum and considered the various approaches to its implementation.

Based on our analysis we made several observations:

1. In terms of Design, studio content, even in fundamental years, is not highly coordinated. Objectives are achieved through individualized projects crafted by instructors with a wide-range of interests and backgrounds. In addition, design fundamentals are the focus well into second year with building design addressed relatively late in the curriculum, usually at the end of second year.

3. In terms of History, survey courses are taught in third year although design and technical discussions of historical precedents take place regularly in second year.

4. In terms of Practice, the present curricular model devotes considerable time to courses addressing technical issues. Although we recognize that this polytechnic model unfortunately biases technology over the humanities, it nevertheless provides ample time to focus on distinct technical topics on structures, environmental systems and construction. Additionally, the current format of Practice courses, i.e. two one-hour lectures and two two-hour labs per week, has great potential not only as an effective way to communicate technical topics, but also to integrate these topics into design studio. The existing content of the
courses and coordination between the lectures, the labs and the design studios does not take full advantage of this situation.

1.1 Recommendations

Based on our observations we made several recommendations regarding the sequencing of courses and their content:

1. In terms of Design, conclude the teaching of design fundamentals in first year and introduce basic building design issues at the beginning of second year to allow for a more integrated relationship between practice and design.

2. In terms of History, move the three-course survey sequence to second year to allow for greater reinforcement of design, social and technical aspects of historical precedents.

3. In terms of Practice lectures, re-format the sequence to avoid isolation of topics and develop the material from general to specific across courses and between years of the curriculum. To be effective, topics need to be carefully sequenced and reinforced over the two-year period that they’re taught. We recommend building in an appropriate level of overlap and reinforcement to develop a deeper understanding of technology topics by students.

4. In terms of Practice labs, develop appropriate but flexible frameworks for integration of technology into Design studios. Given the individualistic approach to Design studio at Cal Poly, we recommend that instructors be provided clear learning objectives that can be achieved through a wide range of approaches rather than highly coordinated projects.

1.2 The Practice Strategy

Practice courses at Cal Poly could previously be characterized as being segmented into basic materials and methods of construction in the quarter one, a focused discussion of Type V construction and working drawings in the quarter two, focused discussion of construction types, site planning and codes in quarter three, and focused discussion of construction systems and specifications in quarter four. This type of segmentation encouraged a disconnection between Practice and Design due to the difficulty with crafting studio projects to address narrowly focused technology topics.

Given the opportunity to rethink the Practice courses, we conclude that the themes of materials, methods, documentation, codes, specifications and site planning are sound, but the sequence in which they are introduced and discussed could be refined. With an eye towards the integration of Practice with Design we re-sequenced the six themes to align them with learning objectives and NAAB criteria for second and third year studios. We also attempted to introduce multiple themes in each course, allowing introductory or general aspects to be addressed early in the sequence and more advance or specific

1.01 Major courses in Cal Poly’s architecture curriculum.
aspects in later courses. This dual strategy of alignment and multiplicity, we reason, will not only parallel the increasing complexity that occurs in the design studio sequence, but also allow an appropriate level of reiteration and reinforcement of Practice issues within and between courses.

In essence, we see the opportunity to create a woven curriculum that takes the sequential content of Practice and relates it horizontally to design studios within a given quarter, while at the same time relating it vertically to other Practice courses from one year to the next. The six themes provide a broad, multi-strand framework for both developing content within the Practice courses and relating building technology to other courses. Our thematic strategy is designed to contract and expand; it contracts to accommodate detailed quantitative discussions of specific technological issues (the “how” of architecture) and it expands to allow for general discussions of how architectural decisions are made (the “why” of architecture).

2.0 Second-Year Practice

Second year is an exciting time to work with students. They are urgently “ready” to propose buildings while at the same time completely naïve about doing so. To teach building science at this level, instructors are responsible for introducing young, impressionable students to the exciting and complex realm of architectural technology. Viewed in that light, it seems imperative to establish a holistic method for approaching technology that prevents it from being isolated from design and other salient issues. At this early stage of their development students need help translating quantitative aspects of their math and physics prerequisites into architectural issues, but is equally important to communicate these issues in qualitative terms.

The strategy for second-year Practice content is to rigorously approach materials and technical documentation, briefly introduce building codes and specifications, and build a strong, if basic understanding of construction types. Knowledge and proficiency in these areas will transfer to design studio through lab projects and will prepare students for third-year practice.

Lab projects in the first quarter are frameworks intended to reinforce both practice and design issues and allow flexibility on the part of individual lab instructors. The emphasis is placed on processes of making that can be integrated into design projects or expanded as stand alone projects conducted in Practice Lab.
ARCH 242 focuses on methods of construction while continuing discussions of documentation and materials begun in ARCH 241. Additionally, building codes and specifications are introduced in order to prepare students for discussions of construction systems and types. This sequence is designed to reinforce to NAAB criteria being addressed in design studio, namely graphic skills, materials and assemblies, technical documentation, and comprehensive design. All four themes carry forward and are developed further in ARCH 341.

The lab project for the second quarter is outlined as a set of design development drawings of a residential-scaled project. As in ARCH 241 the project descriptions are written to allow flexibility on the part of individual lab instructors. If an existing building is used for the main project, it is recommended that a short, graphic design analysis precede the design development set.

2.01 Relationships between second-year Practice lecture topics, Practice lab topics and Design NAAB criteria.

ARCH 241

Although the major focus of ARCH 241 is on materials, the course begins with discussions of documentation and methods. These two themes provide both a context and a vocabulary or language with which to consider materials.

Discussions on documentation begin with an overview of the stages of architectural projects and the wide-ranging structure of design teams, intended to establish the necessity for a clear, commonly held, graphic language of construction. Schematic drawings eventually become the focus of fall quarter since they are most relevant to the level of complexity in second-year Design projects.

Lab project one, designed to reinforce documentation, can be expanded into a stand-alone exercise by lab instructors or integrated into a studio project. An example of the stand alone approach, called “Drawing and Remembering”, asks students to generate a small, but coordinated set of schematic drawings of their childhood home consisting of site plan, floor plan, roof plan, sections and elevations. Students are challenged to give dimensions and apply drawing conventions to a building they haven’t designed, but nevertheless hold dearly in the recesses of their mind’s eye.

Another precursor to materials is the discussion of the principles of construction. Issues such as strength and deformation, stability and movement, thermal transfer and insulation, water and moisture migration and sustainability, are discussed in detail as technical factors that must be considered in the material selection process.

Project two, designed to reinforce the principles of construction, can be expanded into a stand-alone project or related to a studio project. An example of the stand alone approach, “Modeling and Recording”, asks students to study the solar characteristics of their childhood home in its exact location.
Students obtain the solar altitudes and azimuths then graphically translate this data into shade and shadow for morning and afternoon on the solstices. Shade and shadow are plotted in plan and elevation, then recorded in pen and ink.

The material taxonomies addressed in ARCH 241 are wood, stone, fired clay materials, cementitious materials, concrete and metals. Guiding the discussion of each are the composition, origins, properties and production of each material. Examples from ancient to contemporary periods are used to illustrate the evolution in production and construction methods applied to each material in response to changes in technology, sustainability economics and aesthetics.

The final two lab projects are designed to explore materials. Project three requires students to work directly with wood by building a functional object in full-scale. The emphasis is on the basics of woodworking: cutting, sanding, finishing and fitting the wood components by hand so as to develop a deeper personal understanding of the material before moving onto more sophisticated manipulations. One approach to this project, “Cutting and Fitting” is based on the furniture designs of Gerrit Rietveld the De Stijl architect. Students are asked to research Rietveld’s Krat Series in which he proposed simple, inexpensive furniture for the mass market that could be assembled at home by the average person. Students choose one of the Krat designs and reproduce it as accurately as possible; the only variation allowed being the stain used for the selected work. Although the designs are simple, the objectives are profound: building well with one’s hands at full-scale to actualize something that can be tested, and enjoyed, by the user.

Project four asks students to explore the variety of cementitious materials suitable for moving an object from a positive state to a negative state and back again. One approach to this project, “Forming and Casting”, is based on the imaginary landscapes of Isamu Noguchi, designs he envisioned, studied in wax models and eventually cast in bronze. Students researched Noguchi and his work, chose one of the landscapes, modeled it in plasticine clay, cast a plaster mold of the maquette, then cast a final model in plaster. In this and the Rietveld project students learned valuable lessons in making and materiality that can be indirectly bridged to their Design studios. In the process they also gained exposure to two eminent twentieth century designers whose work will appear again in their history courses.

2.2 ARCH 242

ARCH 242 focuses on basic construction methods while expanding the discussion of documentation, continuing the examination of materials, and introducing students to building codes and specifications.

Building on discussions of schematic drawings in the preceding course, ARCH 242 focuses on design development drawings. Although working drawings and specifications are briefly discussed for context, the emphasis in this course is on those drawings situated between the schematic phase and the construction document phase. A thorough understanding of this type of drawing, developed in lecture and reinforced in lab, will prepare students to communicate their design and technical intentions in subsequent studios.

2.11 “Drawing and Remembering” by Jerry Nance (Arens lab).

2.12 “Modeling and Recording” by Matt Weiss (Arens lab).

2.13 “Modeling and Recording” by Evan Fraser (Arens lab).
The discussion of materials in the second quarter focuses on the taxonomies of glass, plastics, composites and coatings. As with earlier discussions, the emphasis is on the composition, origins, properties and production of each material with examples being drawn mainly from the contemporary period. When this discussion concludes, students are expected to have a basic understanding of a broad palette of architectural materials as well as an awareness of the fast pace at which new materials are entering the field in both conventional and novel ways. The CSI format is introduced as a way to classify the wide, ever expanding range of materials and their performance characteristics.

As another precursor to methods, codes are introduced and discussed. The history of codes, types of codes, governing bodies, the trend towards performance codes, and approaches to basic code analysis are briefly discussed.

Methods are discussed in the second half of the course. Students are required to shift from dissecting materials (necessary for a thorough understanding) to constructing components of those same materials (now possible with the knowledge of constituent parts). The components are discussed as construction types which in turn can become a vocabulary of tectonics poised for use in design studio.

The discussion of construction types is grounded with basic tectonic relationships: between form and enclosure, between enclosure and structure, between bearing wall and frame construction, and between monolithic and composite construction. Specific topics are foundation types in wood, masonry and concrete; bearing wall types in wood, masonry and concrete; frame construction types in wood, concrete and steel; bracing strategies for frames; and the roles of cladding for roofs, floors and walls.

The major lab project for the second quarter is to generate a set of design development drawings for a modest-size, residential scale building that may or may not be an original design of the student. The emphasis of this project is on communicating and coordinating architectural (i.e. aesthetic and technical) intentions at a minimum of four scales ranging from the scale of the site to the scale of a detail. The drawing set should include site plan, floor plans, roof plan, sections, elevations, wall sections and details. If the project is based on an existing building, it is recommended that a short design analysis precede the design documentation stage.

One approach to this project is based on The New American House series which presents over 100 residential designs from the years 1985-2002. The authors present sufficient information for students to extrapolate the architect’s design and technical intentions. Students choose one of the houses and analyze the technical means by which design intentions were achieved. They then create an abridged but well-coordinated set of drawings that employ the appropriate graphic and organizational conventions for the design development stage. The analysis and drawings together serve as a fitting example of comprehensive design, one of the key NAAB design studio criteria.
2.21 Chmar House analysis by Sarah Dapper (Arens lab).

2.22 Cook House drawings by Erica Severin (Arens lab).
3.0 Third-Year Practice

The increase in number and complexity of the NAAB criteria from second year to third year suggests that the nature of the lab projects must also become more complex and comprehensive. Two longer projects, one based upon independent research, the other directly related to the Design project reflect this need for a comprehensive approach.

The first third year class, ARCH 341, includes lectures which ask the students to develop insight into the motivations and theories of individual architects and development of building systems, and to discuss the relationship of construction and architectural theory in the 20th Century in a holistic way. The critical readings introduce a student to a broader range of concepts regarding architectural theory in regards to construction, systems and the architects motivation for deciding on a given material or construction method. The readings often stray from the topics of the lectures, but relate to an overall view of construction theory and methodology. The readings also provide a critical voice to compare to the intent of the project or where the project might be located in a continuum.

Sustainability is inherent to a contemporary design strategy. As such, it should not be an area of separate study. The inclusion of sustainability in the third year Practice course curriculum is part of the presentation of all material. Brief considerations of sustainable issues are included in the historical discussion projects as early as the Crystal Palace, in which the manufacturer leased the materials for the building with the intention to reuse the iron. The nature of prefabrication and systems being sustainable approaches to produce buildings is also discussed. ARCH 342 introduces sustainable topics such as green specifications, LEED certification, double skin facades, green roofs and ways of harnessing solar energy with integral systems.

ARCH 341 focuses on the themes of methods and materials using the history of construction, material and systems, and includes a module on site planning. Also included is an overview of codes with an emphasis on zoning issues relating to site planning. The lab projects elaborate on the themes of documentation and specification and reinforce many NAAB criteria.

ARCH 342 focuses on the themes of materials and methods with detailed presentations on the use of various materials in building envelopes. This is supported by with modules on specifications and codes, which address the necessity of research and performance in building envelopes. The lab projects engage the students in independent research as well as applying knowledge gained in the lectures and research to their Design projects. These lab projects are aimed particularly to fulfill the comprehensive NAAB criteria.

3.1 ARCH 341

The content of the lectures in the first quarter of third-year fol-
ows two streams. A historical and theoretical stream presents
the development of systems and prefabricated components,
changes in building materials in the modern era, and the devel-
opment of project teams to create buildings. Essentially this is
a history of building technology beginning in the 1840’s during
the Industrial Revolution and concluding with digital modeling
and manufacturing processes as seen currently with the work of
Frank Gehry. The analysis of systems and components in larger
scale buildings also connects to the same concept presented in
ARCH 242, for smaller scale buildings.

The other stream is the presentation of various building tech-
nology topics beginning with site planning, foundations, zon-
ing and development controls, and later, after the history theory
sequence of lectures winds down, looking at contemporary
systems of buildings using various materials, steel, concrete
etc. The concept which all of these lectures revolves around is
“why?” The methodology of “why” an architect would choose
to use the system is described in historical terms and then in
contemporary technology terms. The student gains an under-
standing of the role played by the development of contempo-
rary building materials and how these new materials influenced
the development of 20th Century architectural theory.

The building typology for the third year classes is commercial
or public buildings, typically three stories or higher. The com-
plexity of construction for this scale of buildings lends itself to
discussions of systems and prefabrication. The overall themes
for ARCH 341 are precedent and analysis. In both the history
and the technology streams the lectures present in-depth dis-
cussions of projects and buildings. Case studies are used to il-
lustrate the design process, technical development, the use of
new materials and construction process. This introduces stu-
dents to the design and construction of complex buildings and
to materiality through detailed precedent and analysis studies.

Another goal of this class is to introduce the student to current
developments in architectural design and the construction in-
dustry, particularly in regards to technology transfer and digital
tools in relation to fabrication and construction of building ele-
ments. This is germane to a contemporary discussion of pre-
fabricated building components and systems. Again, precedent
and analysis is used to study the changing nature of materials
and construction in a contemporary setting.

The lab projects for ARCH 341 include short exercises to rein-
force site design issues, zoning issues and structural patterning.
The major lab project is a multi-week building analysis project.
This project is an in depth examination of real buildings. The
examination is by means of dissection, and inspection of sys-
tems, identifying each system as an assembly, locating the pri-
mary components of each system, and understanding the role
that each system plays in the whole. The intention is to place
buildings in comparison to each other and into the larger con-
text of issues relating to current buildings as they relate to the
real world. The lab instructors develop the projects during the
quarter with consultation. They will be presented to the lab in
the form of three-dimensional drawings and/or models, which
explain the systems separately and in relation to each other.
The sources of information used to develop these comparisons
are professional journals, the construction documents, visits to
actual buildings and interviews with people involved in the de-
sign or maintenance of the chosen examples. The intention to
develop in students the tools to critically evaluate, analyze and
question the built environment that surrounds them.

3.2 ARCH 342

The second third year Practice class, ARCH 342, explores the
materiality of the building envelope and associated structural
systems and how it relates to performance and buildability. The
increase in understanding of architectural issues required by
the student to choose materials appropriate for a design, pro-
vide details and performance information is linked to a design
development process. The focus in this class is primarily on
the building envelope. The content of the lectures includes
information on building envelope performance, material per-
formance, detailing, universal access and egress, and stair and
people moving systems. Guest lecturers are also brought in for
various presentations including; the Architecture Librarian to
discuss research skills, an accredited LEED architect, a sales
representative from Vistawall discussing curtain wall systems,
and a consultant for Building Information Modeling.

The overall themes for ARCH 342 are the issues of research
and performance. This is reinforced across almost all topics
that are covered in lecture. Research is stressed as something
that architects are required to do. And how important research
of codes, materials, specifications and details is to develop a
building. Linked with research is understanding the perfor-
mance of these elements. Performance applies to how materials
behave as well as the achievement of the life safety systems
of a building. This will be reinforced through the students re-
searching and developing their own cladding system relating to
their projects in design studio.

The lab projects for ARCH 342 are intended to guide the student
develop research and detailing skills that will inform them in
the design development process. The first project is structured
to integrate research methods, developing specifications and
performance issues of materials. The second project directly
integrates with the design studio and requires both a general un-
derstanding of the performance of the project relating to codes,
structure and egress, as well as a detailed understanding of the
cladding system used to enclose the project. The student will
design, coordinate and document the decision making process
of design, details, specifications and performance of these sys-
tems in three dimensions. These projects will be coordinated
with the design studio to provide an enriched learning experi-
ce across the discipline strands in the architecture program.

The goal of ARCH 342 is to help students become active and
thoughtful researchers capable of managing independent inves-
tigative study.
3.21 Section from digital model (Taylor: Fower studio).

3.22 Axonometric and physical model (Ceballos: Yin studio).
4.0 Challenges

After completing the first year of this Practice curriculum we would like to pause and critically reflect upon the challenges that still exist in developing this coursework. While there are successes, further improvements can be made in both the lectures and the labs. The following is a summary of these thoughts:

1. The inherited Practice class structure of lecture and lab, i.e. two one-hour lectures and two two-hour labs per week, is a positive aspect of the curriculum, which we would like to use to the best possible advantage. This structure allows for the coordination of the lab to the Design studio.

2. One of the most difficult coordination issues is the coordination of Practice lectures relating to Design. The nature of having eight to ten different studios and projects coordinated with the Practice lectures is almost insoluble.

3. We would also strengthen the integration with the Environmental Control Systems (ECS) classes. Some aspects of ECS are reinforced in the third year Practice classes, but currently these aspects are coincidental to the discussions of material performance.

4. The theme of site planning is the only theme that is also a topic. It is the exception to the thematic strategy. The importance of site planning as a topic, and the reinforcing of connections of the environmental topics covered in second year ECS is something that must be developed.

5. The coordination of projects for Practice labs will need more refinement. In place is a series of flexible projects intended to allow interpretation by Practice and Design faculty, although there is lingering reluctance to adopt them. The creation of longer projects which require research and single-session applied exercises might be more adaptable. Another possibility is to only define learning outcomes and allow instructors devise their own strategies for achieving them.

6. It is necessary to continue the development of reference materials, technology texts, critical readings and contemporary journal articles that are applicable to the lecture content.

5.0 Conclusion

Our overall strategy incorporating six Practice themes woven across four redesigned courses offers a framework on which to further develop the Practice sequence at Cal Poly. These themes are inclusive so as to remain relevant in light of new or refined content in each of our respective courses, and we already see ways they can provide potential linkages to other courses. Our hope is that this horizontal, vertical and progressive strategy for integrating Practice is more than an approach to curricular design, but also a pedagogical platform that demonstrates to our colleagues and students the possibility and the advantage of integrating design, history and technology in a holistic approach to architecture.

Notes: