Utilizing A Capstone Design Project for EC 2000 Assessment

Suzanne D. Bilbeisi, Steven E. O’Hara
Oklahoma State University

Abstract

Architects and architectural engineers should have the ability to coordinate and integrate the many issues involved in the creation of architecture. This requires them to have a basic working knowledge of and sensitivity to several disciplines, as well as expertise in their individual field. One measure of this ability is through a comprehensive capstone design experience. Architecture, as a profession, requires the teamwork of professionals from many disciplines in the course of a typical project. Opportunities for students to experience this interface and interact with practicing professionals seldom occur in academia. The capstone design experience for architecture and architectural engineering students at Oklahoma State University has been specifically designed to allow this experience to occur, and has evolved into a vehicle for EC 2000 assessment.

The School of Architecture at Oklahoma State University was founded in 1909 within the College of Engineering, and shortly thereafter the philosophy of professional education was established that is still followed by the School today:

“The fundamental mission of the School of Architecture is to focus its unique combination of accredited programs in architecture and architectural engineering to prepare and inspire students for the vital professional leadership roles and responsibilities required to shape the physical environment and to have a positive impact on the social, economic and cultural qualities of life in Oklahoma and the entire international context.

The School of Architecture endeavors to instill in each individual a sensitivity to human needs, a genuine concern for quality, integrity and high ideals, a positive attitude for life-long learning, and an appreciation for their own self-esteem.

The School’s primary goal is to provide excellence in professional education for students preparing to enter private practice of architecture and architectural engineering. This professional focus is to educate not just qualified candidates for the degree, but graduates who, during their careers, will be licensed professionals and will assume positions of leadership within the profession and society.”

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In the 1940’s, the accreditation of schools of engineering and of architecture was instituted. OSU’s School was accredited for both Architecture and Architectural Engineering degrees, and has continuously maintained that status to the present. The primary objective of the Bachelor of Architectural Engineering program is to provide basic and professional education to engineering students primarily in building-related structural engineering. The faculty endeavor to produce graduates who possess broad-based knowledge, skills, and judgment that will prepare them to succeed in the profession of architectural engineering or in further studies at the graduate level. The program is designed to prepare the student to contribute to society as a professional engineer dealing with analysis, design, and related activities within the construction industry. Further, the program seeks to utilize the broad resources of the University, to exploit a close relationship with the architecture program and to provide in-depth understanding of the professional field and sensitivity to other less technical concerns related to the building environment faced by architectural engineers. While the primary focus of the Architectural Engineering program is the safe and economical design of structural systems used in buildings, students are also exposed to the basic engineering principles of environmental control systems.

The curriculum is organized to give beginning students time to take most of their courses in general education, while learning about some of the fundamentals in architecture and architectural engineering. This structure gives the student enough background to decide whether to pursue architecture, architectural engineering or some other discipline. The first two years of both curricula are nearly identical, with the only differences in the area of general education. Admission to third year is required for both architecture and architectural engineering students, with the top 30 students in architecture and 15 students in architectural engineering admitted. The last three years of the architectural engineering curriculum are structured such that students take courses primarily in architectural engineering and related subjects. The design studio is a central feature of both curricula; while the architectural design students have eight required design studios, the architectural engineering students share five of these architectural design studio courses along with an additional three architectural engineering design courses within the ten semester plan. The entire architectural engineering curriculum is shown in Appendix 1.

The commonality of the architectural design and architectural engineering curriculums exhibits our fundamental belief in the required cooperative effort of various professionals to create architecture. As Mario Salvadori observes, “Lucky is the client whose architect understands structure and whose structural engineer appreciates the aesthetics of architecture.”

A unique element of both curricula occurs at the fifth year level of the professional School of Architecture. Over twenty years ago, a capstone “Architectural Design and Development” studio was created. In a single semester, architectural engineering students and architectural design students work side by side in the studio with the challenge to completely design a building. They design not only its aesthetic quality, but also its structural system, lighting and HVAC systems from schematic design, to design development, and through the preparation of contract documents. The objective is to help students develop a more comprehensive and mature understanding of the interaction between aesthetic influences and the major technical, legal and human factors that shape the design of most architectural projects.
Students begin the semester by researching data on building codes, site and climate data, anthropomorphic information, and specific requirements pertinent to the functional and technical systems of the proposed architectural problem. A site base model is created to allow each student to study his design in the site with its context. The class works as a whole during this research phase, and then draws conclusions from that information that will influence the development of design solutions.

As the concept search begins, students individually prepare several design options taking into consideration the project siting, the necessary functional relationships, the specific technical requirements, and the legal constraints of building codes. Upon faculty review of each student’s concepts, an individual design direction is set and work progresses towards the Schematic Design phase.
At the completion of the Schematic Design phase, students present their work to a jury composed of practicing professional architects and engineers from the region and others with knowledge of the project. At this point, the students will have articulated a specific concept statement and completed a schematic site plan, building floor plans and elevations at a scale of $\frac{1}{16}$=1′, a diagrammatic structural solution, and an HVAC system delivery diagram. Students also prepare a scaled study model to be placed in the site base for the jury to view. During the presentations, members of the jury provide written and oral criticism and commentary for each individual student.

Once the written comments from all jury members are collated, they are distributed to the students without screening by the faculty. Each student typically receives from ten to fifteen comment sheets from the professional jury members, not all of which are in agreement regarding the student’s project. After considering the jury comments, the students revise their designs and continue working towards the completion of the Design Development Phase. At the Design Development jury, the students discuss the progress they have made in developing their concept, and they prepare and present a site plan, floor plans, elevations, and sections at a scale of $\frac{1}{8}$=1′, a lighting scheme with specific fixtures represented in a reflected ceiling plan, a bay foundation plan and framing plans with all structural members calculated and specified, and an HVAC plan with all duct sizes calculated and specified. Students also create another model of their architectural solution for the jury to view. The architectural engineering students prepare additional enlarged building sections describing their structural design solution, while the architecture students are required to prepare a materials palette board.

At the Design Development jury, the professionals critique the development of the student’s concept and provide suggestions and guidance regarding the multitude of technical choices that each student has made on the project thus far. Again, students receive oral commentary and the written comment sheets from the jurors, and are asked to consider them as they move towards the construction document phase.
The requirements in the construction document phase are very similar to actual construction documents prepared by a professional office, with the exception that written contract specifications and cost estimating are not required. In this phase, students concentrate on the preparation of the documents for their individual solution, with a list of required drawings that includes dimensioned and noted floor plans, elevations and sections, a dimensioned reflected ceiling plan, a circuiting plan for lighting, foundation and framing plans with all members calculated and specified, and an HVAC plan with all ducts calculated and specified. The architectural design students further document an enlarged plan and sectional study of a public stairway, while the architectural engineering students calculate and document a large number of additional structural details applicable to the particular system they are using.
At the close of this phase, each student will have prepared a set of approximately 25 to 35 full size sheets of construction documents using AutoCAD®. The faculty review the construction drawings of all students, and after considering the performance of the students in all phases, select five finalists to be judged in the prize jury by the professionals who have served on the previous two juries. The corporation of Pella® windows and their local distributor, the Womble Company, sponsor the prize by providing money for the individual students who place in the design competition judged by the jurors, as well as additional funds to be utilized for the school’s scholarship trust.
The “Design and Development” studio is one of the courses in our curriculum that satisfies the EC 2000 criteria (a) through (k). Through the process of designing an architectural project, students apply knowledge of math, science and engineering, they analyze data and design a system to meet unique requirements, and they use the techniques, skills and modern engineering tools to identify and solve specific engineering problems. Because the studio is team taught by four faculty: two architects, one architectural engineer specializing in structures, and one architectural engineer with experience in environmental controls, students become familiar with the interdisciplinary teamwork that makes architecture happen and with the multitude of contemporary issues facing engineering and design professionals today, and they gain an understanding of not only their professional ethics and responsibilities, but also those of the related disciplines. This common experience for faculty and students helps reinforce the idea of community within our school, hopefully emphasizing this spirit of community between the professions as well.

As stated previously, members of the profession are invited to review and assess the student work at the conclusion of the schematic design phase, the design development phase, and for the final prize jury. A jury of approximately twenty-five practicing professional architects, architectural engineers, landscape architects and others knowledgeable of the project assemble in the School of Architecture Gallery to review the students’ work on an individual basis. Through formal verbal and graphic presentation, the students describe their design decisions and respond to both questions and comments from the jurors in an organized format. These juries allow the students to exhibit their communication skills, and through the review process, gain an understanding of the impact of engineering solutions in a societal context.
The Capstone design course serves as a vehicle for several assessment activities for the school. In addition to showcasing the course in our regular reviews by the National Architectural Accreditation Board and the Accreditation Board for Engineering and Technology, the “Design and Development” course influences several of our specific assessment strategies. The Outcomes Assessment Committee for the school, founded in 1994, listed in its July 2000 report the following methods to be utilized for assessment:

- Bi-Annual meetings with the School’s Professional Advisory Committee
- Survey of professionals who served on Capstone course juries
- Survey of employers of recent graduates
- Alumni Surveys
- Internal program review and self-study
- Exit Interviews of graduating students
- Portfolios of cumulative student work
- Survey of student attitudes and satisfaction

Internal formal assessment at the college level began in 1999, with the formation of the Engineering Criteria 2000 (EC-2000) Committee. The committee is composed of the Associate Dean, each Department Head and an EC-2000 Coordinator from each department. The committee monitors the progress of each engineering department in preparation for accreditation under EC-2000. This includes development of educational objectives and program outcomes. For the Architectural Engineering program, four constituent groups and their membership have been identified with methods for soliciting input from each.

The first group utilized for assessment studies is our affiliated core of practicing professionals. Since both programs are professionally oriented, having input from professional architects and architectural engineers is critical. The Professional Advisory Committee (PAC), professionals who have served on student juries in the capstone course, and employers of our graduates make up the group of professional constituents. The PAC, a standing committee that has been in continuous service providing support to our school for over twenty years, is today composed of 19 in-state and 8 regional representatives that meet twice yearly at the school. Informal discussion on EC-2000 occurs at these meetings, with a formalized survey scheduled to be performed every two years. While the jury system for the students in the “Architectural Design and Development” studio course has been in place for over twenty years, the formalized survey of professionals for assessment has only been in place the last several years. In response to a formal questionnaire, the jurors found student understanding to be above average in all knowledge areas, with the students’ understanding in some areas judged to be “very well”. The professionals rated the relevance of this course for future architectural engineers as a 6.32 on a 7.0 scale. The complete results of the questionnaire are contained in Appendix 2. Current tracking of graduate job placement has remained constant at 100% over the past decade. While our department head and faculty regularly receive informal input from employers of our graduates, a more formal system to solicit information is planned. Employers of architectural engineering graduates who are within twelve years from graduation will be surveyed every four years.
The second group utilized for assessment purposes is the school’s alumni. The school plans to survey architectural engineering graduates within twelve years of graduation, every four years. In addition, Oklahoma State University performs an alumni telephone survey of all OSU alumni. In the spring of 2000, alumni who graduated between the spring of 1998 and summer of 1999 were surveyed. The Architectural Engineering survey resulted in a 100% response. The survey included 16 questions common to all university graduates and 15 questions developed by the Architectural Engineering or Architecture Faculty. The majority of the architectural engineering graduates surveyed felt that the “Design and Development” studio was a valuable learning experience in preparing them for their professional responsibilities, and some indicated that it was the most useful course in the curriculum that prepared them for their professional career.6

The third group is the faculty. The faculty will provide annual assessment of each course they teach in relationship to EC-2000 criteria (a)-(k). The teaching faculty of each required course in the curriculum will evaluate their course to determine which relevant criteria are being assessed. Because the faculty assigned to the “Design and Development” studio has diverse areas of expertise, this should allow for effortless monitoring that criteria (a) through (k) are truly being met. This system should also assure that the appropriate prerequisite material for the course is being provided by other courses taught by the same faculty. The individual faculty members of all courses will determine assessment methods for each of these criteria. All information will be provided to the Department Head and the Outcomes Assessment Committee, and this information will be included in their yearly report. The faculty as a whole will be provided with the information necessary to perform strategic periodic curriculum reviews.

The fourth group is the current students. The Department Head gives each student who graduates an exit interview. The questions asked during the interview are primarily open ended, but the questions do provide information that is focused towards assessment of EC-2000 criteria. Several students have cited the Design and Development studio as a vitally important aspect of their education in preparing them for the profession. Informally, elected students from all levels of the curriculum provide input to the school through the Architecture School Leadership Council (ASLC). The ASLC meets periodically with the School Head to discuss issues of importance to the health and well being of our school.

These four groups provide a wealth of outcomes assessment information that is processed by the school Head and the school’s Outcomes Assessment Committee. As articulated by EC2000, the need for continual improvement in the professional education of engineers is an ongoing process. These new outcomes assessment tools should significantly help the school to continually improve the relevancy and the quality of education for our architectural engineering students. At OSU, the capstone design experience has evolved into a medium on which several aspects of this assessment rely.

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SUZANNE D. BILBEISI
Suzanne Bilbeisi, an associate professor of architecture, was an instructor of the “Architectural Design and Development” studio course in 1998 and 1999. She also teaches architectural history, and other design studios at all levels of the curriculum. Professor Bilbeisi is a licensed architect in the states of Pennsylvania and Oklahoma, and principal of Bilbeisi Architects in Stillwater, Oklahoma.

STEVEN E. O’HARA
Steven O’Hara is an associate professor of architectural engineering, teaching fundamental and advanced courses in concrete design and structural analysis, and advanced courses in steel and masonry. Professor O’Hara taught in the “Architectural Design and Development” studio course for six years and is currently the EC 2000 Coordinator for the Architectural Engineering program. He is a licensed engineer in Oklahoma.
**APPENDIX 1: Bachelor of Architectural Engineering Curriculum**

Courses common to both Architecture and Architectural Engineering programs are indicated with an asterisk (*)

<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Course Code</th>
<th>Course Title</th>
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<td>*ENGL 1213</td>
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<td>General Education Elective (S)</td>
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<tr>
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<td>American Government</td>
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**First year (fall)**

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<tr>
<td>*ARCH 2116</td>
<td>Architectural Design Studio II</td>
<td>6</td>
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<tr>
<td>*ARCH 2003</td>
<td>Architecture and Society (H,J)</td>
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</tr>
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<td>CHEM 1314</td>
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**First year (spring)**

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<td>Architectural Design Studio II</td>
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<td>*ARCH 2263</td>
<td>Building Systems and Materials</td>
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<td>*ENGS 2113</td>
<td>Statics</td>
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<td>Basic Science Elective (N,L)</td>
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**Second year (fall)**

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<td>*ARCH 2116</td>
<td>Architectural Design Studio IV</td>
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<tr>
<td>*ARCH 3223</td>
<td>Structures: Steel I</td>
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</tr>
<tr>
<td>*ARCH 3233</td>
<td>E. C.: Acoustics and Lighting</td>
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</tr>
<tr>
<td>ENGS 2143</td>
<td>Strength of Materials</td>
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**Second year (spring)**

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<tr>
<td>*ARCH 3243</td>
<td>Structures: Analysis I</td>
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<td>*ARCH 3223</td>
<td>Structures: Timbers</td>
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</tr>
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<td>*ARCH 3453</td>
<td>Computer-Aided Design/ Analysis</td>
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<td>*ARCH 3455</td>
<td>Calculus II (A)</td>
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**Third year (fall)**

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<td>ARCH 4144</td>
<td>Structures: Steel II</td>
<td>4</td>
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<tr>
<td>*ARCH 423</td>
<td>Structures: Concrete I</td>
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<tr>
<td>ENGS 2123</td>
<td>Elementary Dynamics</td>
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<td>MATH 3013</td>
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</tr>
<tr>
<td>PHYS 2114</td>
<td>General Physics (N,L)</td>
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**Third year (spring)**

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<td>ARCH 4443</td>
<td>Structures: Analysis II</td>
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<tr>
<td>*ARCH ---3</td>
<td>Architectural History/Theory Elective</td>
<td>3</td>
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<tr>
<td>MATH 2233</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>ENGS 2213</td>
<td>Thermodynamics</td>
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**Fourth year (fall)**

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<td>*ARCH 5119</td>
<td>Architectural Design and Development</td>
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<tr>
<td>ARCH 5143</td>
<td>Structures: Special Loadings</td>
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<td>*ARCH 5193</td>
<td>Management of Architectural Practice</td>
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**Fourth year (spring)**

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<td>*ARCH 5244</td>
<td>Structures: Concrete II</td>
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<tr>
<td>*ARCH ---3</td>
<td>Architectural History/Theory Elective</td>
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<td>CIVEN 4711</td>
<td>Basics Soils Testing Laboratory</td>
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<td>ENGS 3233</td>
<td>Fluid Mechanics</td>
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<td>ENGS 2613</td>
<td>Introduction to Electrical Science</td>
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<td>Directed Elective</td>
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**Fifth year (fall)**

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**Fifth year (spring)**

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**Total**

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<tr>
<td>160</td>
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APPENDIX 2: Summary of 1999 Outcomes Assessment Questionnaire Completed by Jurors of the “Design and Development” Studio

How well do you feel that the students understand each of the following areas of knowledge?
1-Not at All, 4-Average & 7-Very Well

<table>
<thead>
<tr>
<th>Area</th>
<th>Juror Rating</th>
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</thead>
<tbody>
<tr>
<td>The Architectural Design Process</td>
<td>5.90</td>
</tr>
<tr>
<td>The Role of the Engineer in this Process</td>
<td>4.63</td>
</tr>
<tr>
<td>Architectural Theory</td>
<td>5.31</td>
</tr>
<tr>
<td>Responding to Architectural Context</td>
<td>5.60</td>
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<tr>
<td>The Construction Process</td>
<td>4.54</td>
</tr>
<tr>
<td>Sustainable Design Issues</td>
<td>4.48</td>
</tr>
<tr>
<td>Energy Availability Issues</td>
<td>4.32</td>
</tr>
<tr>
<td>Energy Conservation Concepts</td>
<td>4.69</td>
</tr>
<tr>
<td>The Mechanical Design Process</td>
<td>4.54</td>
</tr>
<tr>
<td>Selection of a Mechanical System (type)</td>
<td>4.41</td>
</tr>
<tr>
<td>Lighting Design and Application</td>
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</tr>
<tr>
<td>The Structural Design Process</td>
<td>5.10</td>
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<tr>
<td>Selection of the Structural System (type)</td>
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</tr>
<tr>
<td>Foundation Design</td>
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</tr>
<tr>
<td>Ethics and Legal Issues</td>
<td>4.75</td>
</tr>
<tr>
<td>The Role of the Architect in this Process</td>
<td>5.48</td>
</tr>
<tr>
<td>Architectural Design</td>
<td>5.93</td>
</tr>
<tr>
<td>Architectural History</td>
<td>5.00</td>
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<tr>
<td>Site Planning Issues</td>
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<tr>
<td>Construction Cost Control</td>
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<tr>
<td>Energy forces which impact the building</td>
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</tr>
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<td>Thermal Comfort Concepts</td>
<td>4.64</td>
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<td>Concepts of Passive Design</td>
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<tr>
<td>Heat Flow/Heating &amp; Cooling Loads</td>
<td>4.39</td>
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<tr>
<td>Design of the Mechanical System</td>
<td>4.12</td>
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<tr>
<td>Architectural Acoustics</td>
<td>4.18</td>
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<td>Structural Building Loads</td>
<td>4.92</td>
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<tr>
<td>Lateral Bracing Requirements</td>
<td>4.52</td>
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<tr>
<td>Social and Human Considerations</td>
<td>5.33</td>
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<tr>
<td>Structural Design</td>
<td>4.92</td>
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<td>Foundation Design</td>
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<td>Ethics and Legal Issues</td>
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<td>Lateral Bracing Requirements</td>
<td>4.52</td>
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<tr>
<td>Social and Human Considerations</td>
<td>5.33</td>
</tr>
</tbody>
</table>

Based upon your understanding of the course, ARCH 5119, how would you rate its relevance:
1-Not at all Relevant, 4-Relevant & 7-Very Relevant

For future Architects? 6.61 For future Architectural Engineers? 6.32

How well do you feel that the School of Architecture succeeds in developing each of the following attitudes in its students?
1-Not at All, 4-Average & 7-Very Well

<table>
<thead>
<tr>
<th>Attitude</th>
<th>Juror Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desire for excellence</td>
<td>6.37</td>
</tr>
<tr>
<td>Professional Attitude</td>
<td>5.93</td>
</tr>
<tr>
<td>Self-Motivation</td>
<td>6.15</td>
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<td>Competitive Spirit</td>
<td>6.05</td>
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<td>Positive Self-Concept</td>
<td>5.79</td>
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<tr>
<td>Responsibility to Society</td>
<td>5.57</td>
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<td>Open Mind</td>
<td>5.56</td>
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<tr>
<td>Positive Attitude</td>
<td>6.12</td>
</tr>
</tbody>
</table>

How well do you feel that the students have developed each of the following skills?
1-Not at All, 4-Average & 7-Very Well

<table>
<thead>
<tr>
<th>Skill</th>
<th>Juror Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architectural design skills</td>
<td>5.98</td>
</tr>
<tr>
<td>Verbal communication skills</td>
<td>5.05</td>
</tr>
<tr>
<td>3-D/graphic communication skills</td>
<td>5.63</td>
</tr>
<tr>
<td>Technical design skills</td>
<td>5.13</td>
</tr>
</tbody>
</table>

Overall, how would you rate the following programs of the School of Architecture?
1-Below Average, 4-Average & 7-Above Average

<table>
<thead>
<tr>
<th>Program</th>
<th>Juror Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Architecture</td>
<td>6.32</td>
</tr>
<tr>
<td>Architectural Engineering</td>
<td>6.29</td>
</tr>
</tbody>
</table>