A Four-Year Path to Synthesis: The Junior Interdisciplinary and Vertically Integrated Design Experience

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ABSTRACT

Engineering industries are calling for graduates that have a breadth of skills including design and analysis skills, teaming skills and “soft skills” (i.e., project management, concept value analysis, communication, cross-disciplinary understanding, etc.). Furthermore, concepts that are traditionally taught in isolated packets are difficult to synthesize and apply to the more holistic problems engineers typically face.

Northern Arizona University’s College of Engineering and Technology is implementing an innovative, four-year, sequence of classes called the Path to Synthesis. The sophomore and junior courses in the Path to Synthesis program are team-taught industry simulations which use collaborative product design to not only develop design skills, teamwork skills, and soft engineering skills, but to also encourage the use of state of the art design methods and professional-quality software tools. These two classes are each divided into divisions consisting of 8 to 9 students from the engineering disciplines of Civil/Environmental, Electrical, Mechanical and Computer Science. Each division is managed by a faculty member who role plays as a division manager.

This paper describes the piloted junior level Path to Synthesis course, called EGR 386 Engineering Design III - The Methods, which is vertically integrated with the sophomore course, EGR 286 Engineering Design II - The Process. The junior course emphasizes analytical engineering skills along with sophisticated project management techniques including subcontract management. Written and oral communication skills and topics on professionalism and ethics are also addressed. Greater emphasis is placed on rigorous planning and scheduling, cost estimation and economics, and coordination of efforts between: the Design II and III teams, the Design III students and the customer, and the Design III students and students from the Computer Visualization and Imaging (CVI) program at Cogswell College in Sunnyvale, CA.

The Fall ‘95 project was the design of a materials recycling facility (MRF) for co-mingled curbside household recyclable garbage. The students designed and constructed feasibility models of fully automated and computer controlled mechanisms that sort items such as aluminum, steel, various grades of paper, cardboard, plastics types, and contaminants. A local site was selected and a task force of the sophomore and junior Civil and Environmental engineering students worked concurrently on site development and the MRF design. The junior Civil and Environmental students subcontracted with students from Cogswell College to produce computer animated renderings of the site before and after site construction.

BACKGROUND

The call for reform in engineering education has been widely discussed in various conferences, journals, and forums for several years (Evans et al., 1990; ASEE Engineering Deans Council, 1994; and NSF DUE Restructuring Engineering, 1995). Industry and society are no longer satisfied with traditional undergraduate engineering programs that provide only a limited exposure to design and synthesis (McMasters and Ford, 1990; Tadmore, et. al., 1987; and Tarricone, 1990).

The natures of both the engineering profession and student body are changing. In addition to fundamental technical skills, industry now expects engineering graduates to possess: practical hands-on abilities, project management skills, multi-disciplinary insights, computing literacy, critical thinking aptitude, communication skills, interpersonal talents, and an understanding of the societal environment within which the engineer practices (Betts, et. al., 1994; McMasters and White, 1994). NAU industry recruiters combined with NAU's College of Engineering Industrial Advisory Council (CAC) echo the same message. In short, industries and society need engineers who can "design" in the broadest sense of the word.

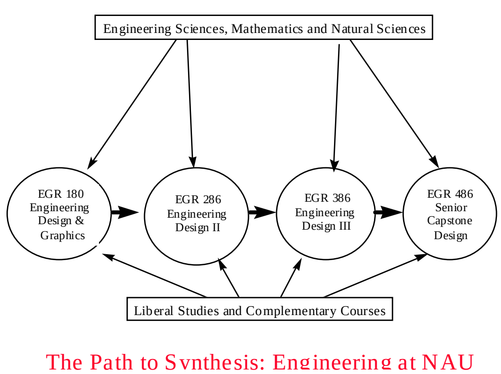

Figure 1 Path to Synthesis - Design at NAU

In response to the changing needs of the engineering industry and to our desire to strengthen the undergraduate engineering education at NAU, the College of Engineering and Technology (CET) has been planning and implementing an innovative, four-year sequence of classes called the Path to Synthesis.

The Path to Synthesis is unique in many ways. The courses are integrated horizontally by forming students into interdisciplinary design teams. Vertical integration is achieved through collaboration between students in the sophomore and junior courses, EGR 286 Engineering Design II -The Process and EGR 386 Engineering Design III - The Methods. Engineering Design II and III are team taught by a cadre of faculty from each of the engineering disciplines at NAU. It is the teaching team's intent to geographically distribute the design process, utilizing graphical design students from Cogswell College.

It is the CET's goal to require participation by all engineering students in the complete design path by 1996. This paper describes the junior experience within our first combined offering of Engineering Design II and III. A brief description of Engineering Design II is also provided.

ENGINEERING DESIGN II

The primary objective of the sophomore design course is to introduce students to the engineering environment as found in professional engineering organization. Students are exposed to that environment in the context of an engineering design cycle simulated during a semester-long project. This simulation is enhanced by having an interdisciplinary team of faculty members who play the pre-defined roles of division managers, chief engineers, and a company president as shown in Figure 2.

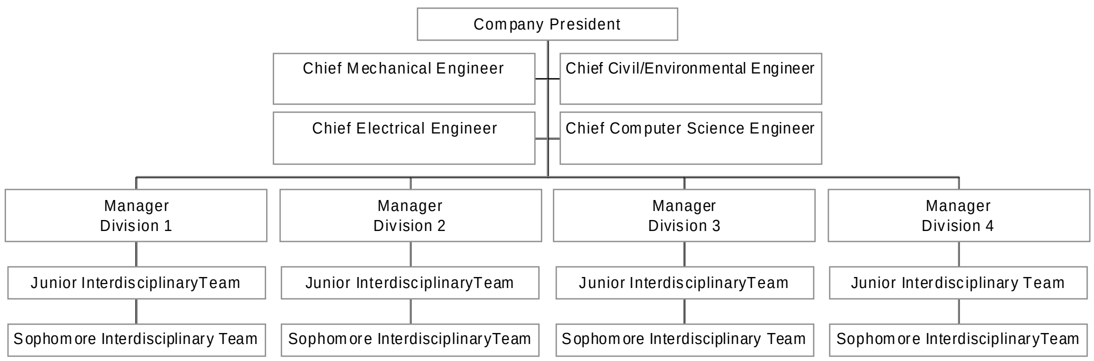

Figure 2 Company Structure

Students play the role of engineers who have been recently hired into a midsize engineering firm. As engineers in the company, students are members of a team in one of many divisions. Each team consists of two majors from each discipline including civil or environmental engineering, computer science and engineering, electrical engineering and mechanical engineering.

After being introduced to the company's culture, and learning their roles in the organization, students are presented with an engineering problem by a customer. The remainder of the course is spent completing requirements capture, problem analysis, designing, building, and testing a solution. During the initial offering of Engineering Design II in the Fall 1994, the student teams developed computer-controlled robotic devices to retrieve hazardous waste from a high-risk area following an earthquake. The details of this project are highlighted in the paper by Howell, et. al. (1995). Engineering Design II is structured so that students receive information just-in-time. The ideas presented are immediately applicable to the current project phase. New material, that supports the design process and the project technology, is presented in a wide variety of ways including: role playing, short exercises, in-class activities, open discussion, etc. Lecturing is reserved for topics that do not lend themselves to more interactive teaching methods. When lectures are required, they are limited to short 20-30 minute information bursts with a brief question and answer session following.

ENGINEERING DESIGN III

Goals and Objectives

Engineering Design II is a prerequisite course for Engineering Design III. The intent of Engineering Design III is to emphasize analytical engineering skills and design along with sophisticated project management ideas, subcontract management, partnering, written and oral communication skills, and topics on professionalism and ethics. Greater emphasis is placed on rigorous planning and scheduling, cost estimation and economics, and coordination of efforts between: the Design II and Design III teams, the Design III students and the customer, and the Design III students and students from the Computer Visualization and Imaging (CVI) program at Cogswell College in Sunnyvale, CA. As Engineering Design III becomes fully integrated into our curriculum, the junior-level students will be expected to apply sound engineering principles to their task, as opposed to the intuitive approach that is permitted in Engineering Design and Graphics and Engineering Design II.

Course Overview

To accomplish the stated goals, an engineering design simulation of a semester-long project is conducted. The methodology is the same as the techniques employed in Engineering Design II, except now the sophomore and junior level courses are offered concurrently.

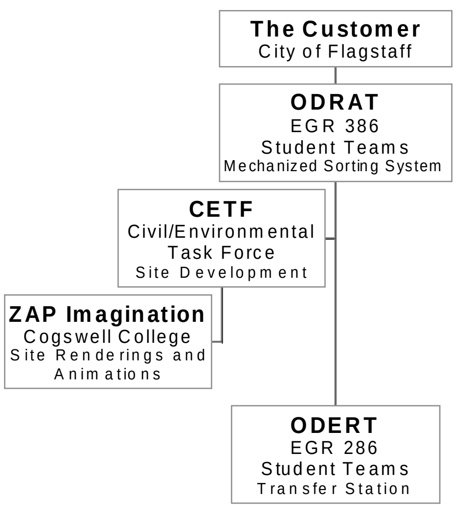

Figure 3 The MRF Project Structure

Each Engineering Design III team as shown in Figure 3 is responsible for the complete project as presented by the customer. The four teams create four unique designs with an aspect of team competition present. The junior-level teams are paired with counterpart sophomore teams. The sophomore teams are assigned a component of the project which they complete by partnering with their companion upper-classmen. In addition, other project components are subcontracted out to specialized student teams. The junior students are in effect the general contractor hired by the customer. They must bring together diverse elements and inputs into a single effort and must marshal and allocate resources.

The teaching team consists of four faculty members with one member from: civil/environmental, computer science, electrical, and mechanical engineering. Each faculty member assumes two roles: as division manager and as a chief engineer in their specialty field. CET's co-op director, who has an expertise in TQM, acted as the company's president. In addition, the teaching team draws upon the expertise of outside personnel to supplement the activities of the course. An environmental attorney acted as our company lawyer. He provided guidance on site development activities.

Design Project + Design Process = Course Structure

It is the careful selection and design of the student project which motivates the teaching and learning of the entire design process. In turn, it is the design process which provides the course pedagogical structure. A successful course depends strongly on the appropriateness of the project. The characteristics of a successful project include:

- It is believable
- It encourages creativity
- It can be effectively prototyped
- It incorporates the course concepts
- It includes multi-disciplinary tasks
- It has some well-defined constraints
- It contains uncertainties and incomplete information
- It may be plagued by unforeseen disasters or blessed with breakthroughs

A project-driven course provides a flexible course platform to introduce state-of-the-art tools and to investigate timely social issues within the context of an engineering solution. On the other hand, the size and complexity of the project must be carefully considered. A small and/or simple project may be easy to administer, but provides little incentive for the students to stretch and test their management and technical skills. A too large and/or complex project may overwhelm the course and interrupt the transfer of additional information that is not directly related to the project or interrupt the flow of student-generated deliverables. The teaching team continuously explores and evaluates projects with the hope of finding the right balance.

Project Overview

Although the project for Engineering Design III and II will change from semester to semester, the Fall 1995 project was a materials recycling facility, also known as a MRF. Household co-mingled recyclable materials are picked up at curbside and are delivered to the MRF for sorting and resell within the recycled materials market. The types of materials sorted include aluminum, steel, tin, various grades of paper, cardboard, glass, and plastics. The students were responsible for the entire process of designing a MRF for the City of Flagstaff and demonstrating the success of their designs with scaled-down prototypes that sorted simulated co-mingled waste. The students were encouraged to perform an economic value analysis on the types of materials they selected to sort. They researched the recycled materials market to determine the going market rate, the percent contaminant acceptable, and acceptable material combinations.

The Project Customer

Early in the course, the “customer”, Mr. Ben Fisk - Solid Waste Superintendent for the City of Flagstaff, presented the MRF problem to the sophomore and junior students. Mr. Fisk asked the student teams to prepared a MRF bid that included the site-development design; an automated, computer-controlled, state-of-the-art MRF design, and a working prototype. The students were given approximately fourteen weeks to complete this request.

Mr. Fisk explained that the City was in the process of purchasing a parcel of land that the MRF company must develop, use, and lease from the City. The City would pay a fee to the facility for the processing of materials that will be based upon the amount of delivered tonnage. In addition, the MRF and the City will share in the sale of reclaimed commodities. The facility must include a public-education component that provides access to the working areas for public viewing and a educational center for use by tour groups. Mr. Fisk also supplied projected waste-volume data and truck-flow information to the students.

The Transfer Facility

As indicated by Figure 3, the front-end portion of the MRF was subcontracted to the sophomore students in Engineering Design II. This entailed the design and construction of three major components: garbage truck and passenger car traffic control onto and through the MRF site, the automated tipping floor (where the material is dumped), and a computer-controlled transport system that moves material from the tipping floor to the sorting mechanism.

The students were given a great deal of leeway with their transfer facility designs. Physical constraints due to site layout and traffic volume were well-defined by a Civil and Environmental Task Force (CETF) and the customer. To enhance computer control aspects, the teaching team added a few nominal traffic control requirements such as monitoring garbage truck traffic, directing trucks, and reporting traffic status. In addition, all data was displayed on a CRT display through a computer interface, permitting operator intervention.

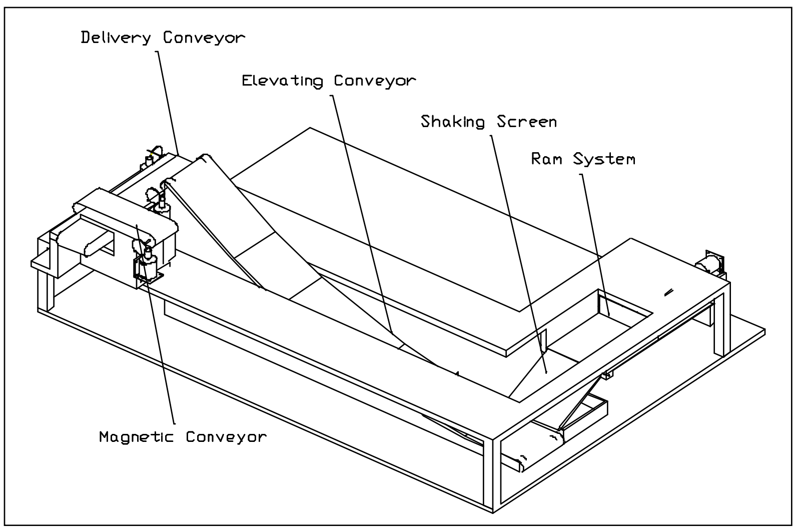

Figure 4 Division Three's Tipping Floor

Each Sophomore team solved the problem of efficiently transporting recyclables differently. The students were encouraged to actively search the literature and to examine existing MRF designs for the purpose of identifying solution alternatives. Early in the semester, the two classes took a day-long field trip to Phoenix to visit CRINC's state-of-art MRF and the City of Phoenix's hallmark Transfer Facility (Conner, et. al., 1994).

The search of external sources proved useful. One of the sophomore teams creatively identified eight different material transfer schemes; a tilted tumbler, a slide, a conveyor belt system, a tube, an auger drive, a spinning plate, a launcher, and a rotating wheel. The final design, the rotating auger drive that moved recyclables up from the pit through a tube at a constant rate, was selected using the structured concept selection methodology offered by Ulrich and Eppinger (1995). Another design (Bellman, 1995), which is shown in Figure 4, utilized a moving ram, a system of conveyor belts, a shaking screen presort of fine contaminants, and a magnetic conveyor presort of ferrous materials.

The integration of the transfer facility to the sorting mechanism demonstrated the need for effective communications between the sophomore and junior student teams. Some of these integration issues included proper interfacing of computer controls, delivery height requirements, material flow rate and material characteristics, and pre-sorting. Good communications were facilitated by good planning and scheduling. To encourage the use of these tools, the students were assigned a scheduling assignment prior to their implementation of the project plan.

The Mechanized Sorting System

The Engineering Design III interdisciplinary student teams not only worked on the sorting mechanism, but were also responsible for the coordination of effort with their counterpart Sophomore teams and the communication with the customer. The MRF specification/proposal document reflects this type of integrative management. The sophomores provided to their counterpart junior team, a transfer facility specification document. The junior team, in turn, prepared a complete customer-oriented specification that incorporated the transfer facility information along with the sorting mechanism specifications.

It is not a trivial problem to automatically sort all co-mingled recyclables. Today, it is common for the real-life MRF to utilize mechanical devices to separate aluminum, ferrous materials, cardboard, paper, plastic, and glass. The separation of paper grades, plastic types, glass color, and contaminant, however, is done by human pickers. The junior teams were required to avoid the human solution and mechanically sort high grade paper, newspaper, HDPE plastic, PET plastic, and contaminant.

The system solutions chosen were very inventive and included a combinations of various air distillation schemes, water float/sink tanks, inclined conveyors, and vibrating conveyors.

Civil and Environmental Task Force (CETF)

A primary goal of the corporate simulation was to give students in each of the engineering disciplines a significant experience with the concepts and practice of their own specific engineering field. For the civil and environmental engineering students this experience was provided by the site design and development phase of the MRF project. The students examined issues such as traffic control, city zoning and land use codes, storm drainage and control, environmental regulations, traffic flow and scheduling, roadways, and permits. Because the civil engineering tasks were numerous and significant, the teaching team decided to combine all the civil and environmental engineers into a single task force to address these issues. Both sophomore and junior civil and environmental engineers were combined into a single team of approximately 20 students.

The civil and environmental task force developed a group management plan and elected team officers. The individual tasks were assigned as action items to individuals and subcommittees within the civil and environmental task force. The specific sub-tasks were: the procurement of topographic data, both in hard and digitized forms; a cross-sectional analysis of the 20-acre site; the selection of the combined building and parking lot site as a function of easement, screening, drainage, and traffic requirements; a traffic analysis that accompanied the intersection design; an examination of flood plain characteristics and flood plain zoning; and the preliminary design of culverts and a retention basin. The CETF efforts culminated in a preliminary site design that located the building, parking lot, and all the roads. This site design was then subsequently used by the other teams in the design and construction of the transfer facility and sorting mechanism.

Virtual Project Work Teams

During the Fall, 1995 semester, NAU students were introduced to the paradigm of virtual work teams through collaboration with Cogswell College students. Because the collaboration involved the design of the building site, the CETF had the primary responsibility of interacting with the other institutions.

NAU civil engineering students "hired" students from the Computer and Video Imaging (CVI) department at Cogswell College in Sunnyvale, California to generate a computer produced rendering of the site before and after the development. Cogswell CVI students also produced a computer generated animation fly-by of the site after the roads, landscaping, and buildings were constructed.

The collaborative effort between NAU and Cogswell students required the following five steps:

- submission of a Request for Proposal (RFP) from NAU to Cogswell.
- receipt of Proposal from Cogswell CVI students to the NAU civil and environmental task force
- compiling and submission of GIS (Geographical Information System) files that were mutually compatible with the software used by both Cogswell and NAU (AutoCAD dwg format)
- submission of CAD generated overlays of the site development plan to Cogswell (includes roads, cut and fills, water catch basin, parking lot, etc.)
- submission of aerial photographs of site to Cogswell

Cogswell students generated a 3 dimensional surface from the topographical GIS file given in 2 foot elevation increments furnished by NAU. Using a digital scan of the aerial photographs, they overlaid this surface with trees, rocks, landmarks, etc. and produced a color rendered view of the site before development. In the second stage, they overlaid the CAD files onto the site, and re-rendered for an "after" view of the site. 3D studio software was then used to create an animated fly by of the site for use in the final presentation by NAU engineers.

THE SEMESTER IN RETROSPECT

In lieu of a traditional final exam, each student was required to submit a post mortem report that addressed the following two questions: (1) Describe the design cycle and how this process related to your team's project. How was each step applied? List and describe any specific tools, techniques, and resources that were used. Evaluate how well you and your team applied the process to your project. (2) Reflect upon the challenges and successes you personally encountered during the semester. Describe the decisions that you made that contributed or hindered the project. What, if any, technical lessons were learned? What problems did the team encounter?

Some of the reports were quite detailed and provided to the teaching team many valuable insights to assist in the planning of future offerings of the Engineering Design III - The Methods. The following sub-sections summarize and reflect upon the comments written by the junior students; students who had piloted the sophomore course a year earlier.

Team Dynamics and Communications

It was clear that team dynamics and communications were hardly problems for this seasoned group of students. In the past, this topic dominated the post mortem discussions. The junior students were so savvy in these areas, that there was very little apparent need to discuss. “Within two weeks after the start of the semester, students were already trusting in each other and working well together” (Levine, 1995).

The junior students, who had been previously introduced to e-mail in Engineering Design II, made extensive use of this medium to keep each other informed. In addition, they electronically posted questions and discussions to the customer and the management team. Even though it was not a management requirement, one team kept an annotated team notebook to record daily events.

Pedagogy

The teaching team expected a smooth application of the design process structure to the project by the juniors. For various reasons, this did not happen; resulting in a less than successful project and classroom experience. The teaching team provided a great deal of guidance early in the semester by coordinating team activities and exercises, aiding in requirements capture, and providing opportunities to research the problem. The design project, design process, and course structure began to breakdown however shortly after the student teams handed-in their first major deliverable, the specification document. It was at this time, that the faculty team stepped back from the process, in hopes that the students would initiate their own structure based upon their previous year’s experience. “Brainstorming and other related process steps were put off, waiting for the management team to get the ball rolling”(Hale, 1995).

Although this particular group of students were familiar with scheduling and its importance to the design process, it was a tool that was under-utilized. Many students recognized, in retrospect, that a thoughtful plan and schedule would have solved most of their problems. There were disagreements regarding who was doing what, who had done what, and when things were going to get done. Each team experienced the crisis of implementing, testing, and debugging in the “eleventh hour”.

As presented by the customer, the project was overwhelming. The students were thrown off track by minor, secondary issues that were not part of the final feasibility models. The juniors had difficulty defining their roles, assuming project responsibilities, and reducing a complex system design into smaller, individualized tasks. Compared to their previous sophomore project, “the amount of responsibility and needed technical skill had increased two fold” (Mitchell, 1995).

It is the teaching team's intent to emphasize the application of analytical tools to the design project in Engineering Design III. The teaching team found it very difficult to coordinate the transfer of methods knowledge to the junior students in the combined class offering. The initial course plan was also at fault. The topics were not carefully coordinated with the project phases and the information that was presented did not flow well with the project tasks at hand. During the last 8 weeks of the semester, there was the overwhelming tendency to let the project activities dominate over in-class teaching and the application of analytical methods. On the other hand, those students who did challenge themselves and the project did benefit. "The circuit we designed and implemented to perform the sequential startup/shutdown of motors without computer logic used all of the electrical engineering courses I have taken so far. In addition, there were design aspects that required us to go beyond our current educational level" (Parker, 1995).

Facilities

The traditional classroom space has proven to be problematic with the large number of students that concurrently participated in Engineering Design II and III. The standard lecture classroom that is rectangular and is composed of rectangular, 3-person tables limits the effectiveness of team meetings that require, at a minimum, round-table type facilities. Simultaneous small-group team meetings produced so much noise that teams were unable to conduct meetings effectively. Even large group/company meetings were difficult to conduct in this environment due to poor acoustics and the difficulty to move in and around a capacity crowd. The student teams creatively addressed the physical space problems by finding areas other than the in the assigned classroom to conduct their meetings.

Limited space and facilities for constructing and testing prototypes hindered the student's progress. Some of the teams chose to work off campus, in their garages, which often limited access to the project by members of the same team. One team moved their project into another lab and "borrowed" CET's machine shop equipment to machine, mill, and weld parts. Lacking the right tools to cut Plexiglas, one team member, initiated contact with NAU's Central Machine Shop. Their personnel not only helped this student with the Plexiglas problem, but taught the student basic shop tool usage.

CET is actively working to correct this project-construction problem; a problem that is not unique to EGR 286/386 sequence, but has also impacted senior capstone design projects and other special projects like the electric race car, the human-power vehicle, the mini-Baja vehicle, and the concrete canoe. CET has recently procured numerous machining tools and CNC machines for the purpose of developing a student machine shop. The lab is nearly complete and will be monitored by CET's Instrument Maker.

Preliminary Site Development and the Virtual Design Component

The teaching team and students both believed that the preliminary site development and the virtual design component activities were very successful. The participating CETF students rose to the challenge presented. Within a relatively short period time the students gathered and assimilated the information pertinent to the task and finalized the MRF site design. The CETF site design survived the scrutiny of both the MRF project teams and the Cogswell students. CETF had two strong sophomore student co-leaders who kept the task force on track and on schedule. In addition, the CETF junior students shared a great deal of technical knowledge, enabling the sophomore worker bees to take on tasks that they had no formal academic training in. The one negative aspect to the CETF experience was the difficulty many of the CETF students had in catching up with their respective MRF teams once the CETF commitment ended.

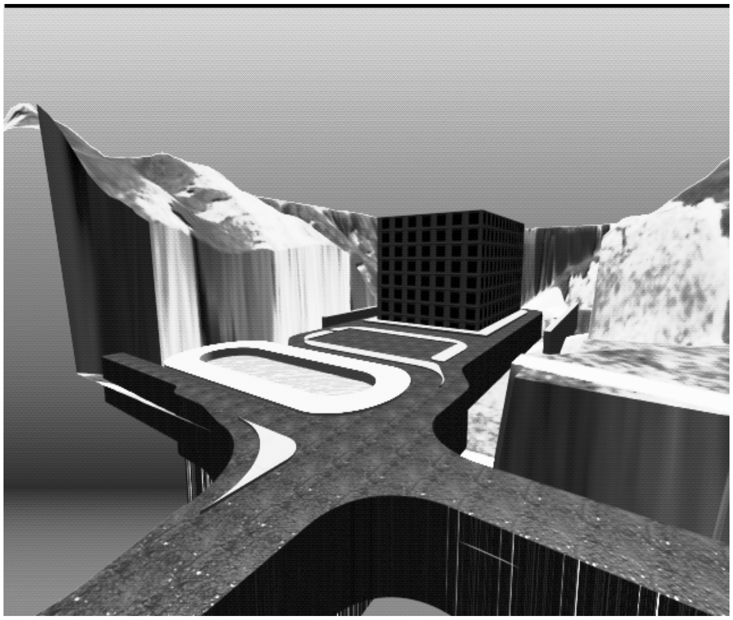

Figure 5 CVI's Site Rendering

Our first experiment with virtual design provided the opportunity for some students to become both a client and project manager. The students learned the value of concise and timely communication and became comfortable with different modes of communication. The final Cogswell product came in on time and met the RFP requirements. The "devil is in the details" however, and the Cogswell renderings shown in Figure 5 clearly pointed this out. The site contours were taken at twenty-five foot increments instead of the provided two foot increments. A rolling topography became the Grand Canyon. The MRF industrial complex with a run-off water recharge basin, became a up-scale office complex with a shimmering blue pool of water.

The faculty team is pursuing external funding to purchase teleconferencing equipment for both CET and Cogswell. The virtual design component will be continued and enhanced in subsequent sophomore and junior classes.

SUMMARY AND CONCLUSIONS

The pilot offering of EGR 386 vertically integrated with EGR 286 did not completely meet the expectations of the both the teaching team and students. The offering clearly pointed out the difficulty of coordinating activities amongst the various student academic levels and disciplines. The faculty team is carefully evaluating the successes and problems of the combined design offering and is entertaining other ways of implementing a junior-level interdisciplinary design experience that emphasizes advanced project management and the application of analytical tools to a design projects. Even with its problems, the EGR 386/286 students expressed enthusiasm for the design sequence. "I have learned a lot about the design process, I am more confident about approaching problems, I am more equipped to come up with solutions, and I feel confident about working in a team, using the design cycle to our advantage" (Colvin, 1995).

REFERENCES

Bellman, W, (1995), *Fall 1995 EGR 386 Project MRF Design Document for Division 3,* A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

Betts, M., S.J. Rickard Liow, and R.W. Pollock, (1994), "Different Perceptions of the Importance of Educational Objectives", *J. of Professional Issues in Engineering Education and Practice*, ASCE, 119(3), pp. 317-325.

Colvin, J., (1995), *Fall 1995 EGR 386 Post Mortem Report*, A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

Conner, K.R., R.C. Brockway, B.E. Henning, (1994), "Taking the Trash Out of Hiding", *Civil Engineering*, February, pp. 40-43.

Engineering Deans Council and Corporate Roundtable, (1994), "Engineering Education for a Changing World", Joint Report, American Society for Engineering Education.

Evans, D.L., B.W. McNeill, and G.C. Beakley, (1990), "Design in Engineering Education: Past Views of Future Directions", *Engineering Education*, July/Aug., pp. 517-522.

Hale, D., (1995), *Fall 1995 EGR 386 Post Mortem Report*, A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

Howell, S.K., K.W. Collier, D.S. Larson, J. M. Hatfield, G.W. Hoyle, and G.A. Thomas, (1995) "An Integrated Engineering Design Experience: Freshman to Senior Level", *1995 ASEE Annual Conference Proceedings*, Anaheim, CA, June 25-28, 53-55.

Levine, R., (1995), *Fall 1995 EGR 386 Post Mortem Report*, A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

McMasters, J. and S. Ford, (1990), "An Industry View of Enhancing Design Education", *Engineering Education*, July/August, pp. 526-529.

McMasters, J.H. and B.J. White, (1994), "Report on the Second Boeing-University Workshop On: An Industry Role in Enhancing Engineering Education", July 18-19, 1994, The Boeing Company, Seattle, WA.

Mitchell, C., (1995), *Fall 1995 EGR 386 Post Mortem Report*, A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

National Science Foundation Division of Undergraduate Education, (1995), "Restructuring Engineering Education: A Focus on Change", Report on a NSF Workshop on Engineering Education, March 17, 1995.

Parker, J., (1995), *Fall 1995 EGR 386 Post Mortem Report*, A Student Report, College of Engineering, Northern Arizona University, Flagstaff, AZ 86011-1560.

Tarricone, P., (1990), “Education at a Crossroads”, *Civil Engineering*, October, pp. 74-77.

Tadmore, Z., Z. Kohavi, A. Libai, P. Singer, and D. Kohn, (1987), “Engineering Education 2001”, *Engineering Education*, Nov., pp. 106-124.

Ulrich, K. and S. Eppinger, (1995), *Product Design and Development*, McGraw-Hill, Inc.

DEBRA LARSON

Debra Larson recently joined the College of Engineering and Technology as an Associate Professor after completing a Ph.D. in Civil Engineering from Arizona State University and working in industry for ten years. Dr. Larson is a registered Professional Engineering and teaches, in addition to Engineering Design II and III, senior structural design classes in Concrete, Steel, Wood, and Masonry. Debra’s research interests include alternative building materials, low rise structures, and engineering pedagogy.

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Steve Howell is an associate professor of Mechanical Engineering at Northern Arizona University. He received his Ph.D. degree from the University of British Columbia in 1983. His MS and BS degrees in mechanical engineering were received from Southern Methodist University in 1977 and 1976. Prior to joining the engineering faculty at NAU, Steve taught various mechanical engineering courses at University of the Pacific. From 1986 to 1987 he worked with the College of Engineering at the University of Zimbabwe under a US Agency for International Development grant. While in Zimbabwe he helped install and implement the first computer aided learning lab in Sub-Saharan Africa. Steve’s interests are in computer aided design and engineering.

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