The Challenge Of Preaching To No Choir:
How Mindset Can Make Or Break A Course

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ABSTRACT
Students taking a course required for their major know that the materials the course covers fall almost entirely within their chosen area of interest. Generally, instructors like to teach such courses because their audience shares almost the same mindset. This gives a feeling that everyone in the classroom is on the “same wavelength” because all speak the “same language”.

Elective, interdisciplinary courses, on the other hand, are different. The interests and expectations of those taking an interdisciplinary course can make or break that course. Students select their courses with certain expectations. Before settling on a course, students weigh factors such as the subject, rigor, instructor, and ability to do well. Developing a new interdisciplinary course can be tricky especially if the course is geared toward engineering and liberal arts students and includes both engineering and non-engineering materials. Students taking such courses are usually diverse from many backgrounds and share little in terms of mindset. Granted, this could be an environment where wide range of ideas are exchanged and where debate flourishes, but it can also be a climate where some feels disconnected and isolated.

A new interdisciplinary course that combines engineering arts and the liberal arts has been developed and offered. The course materials were designed to appeal to both engineering and non-engineering students. The class was equally split between these two groups of students. The course required high technical skill and ability to operate advanced software, which some did not possess. The course explored the tightly knit relationship between the art of constructing some of the most sophisticated projects and other non-engineering requirements such as political, economical, historical, cultural, and public perception factors. The course offers an insight into the role engineers play to find a common ground that satisfies all needs and meet mandated regulations.

INTRODUCTION
Located in the Capital District of the State of New York State, Union College was founded in 1795, the first college chartered by the State’s Board of Regents. Union is an independent, liberal arts college with engineering.

In its Vision Statement, Union College states “Our graduates will be people inspired to make a difference in the world, who know how to use academic methods of inquiry to bring about beneficial change. They will be equipped to address complex 21st-century societal and intellectual challenges that require the ability to interact perceptively with people of many backgrounds and viewpoints. They will be able to think critically and creatively, with an informed sensitivity to aesthetic and ethical concerns.”

Furthermore, in its Mission Statement, one of Union’s major goals is to further integrate engineering with the liberal arts. The college recognizes that “students graduating from Union belong to a generation in which technology has revolutionized communication and that they are part of a world where the understanding and appreciation of a multiplicity of cultures and perspectives will be essential to their success.”
The college acknowledges that “preparing students for the 21st century requires that we take Union to new frontiers of technology and beyond frontiers of nations and cultures. When Union developed a ‘balanced education’ during the mid-19th century, this concept – designed in response to the needs of a nation characterized by rapid industrial and urban growth – was understood as parallel studies in the liberal arts and in science and engineering. The introduction of engineering into the liberal arts curriculum was a matter of preparing students to succeed in that changing world. Today science, engineering, and technology join the humanistic core of the liberal arts as essential to every aspect of human endeavor. In such a world, where interdisciplinarity has become indispensable in most fields, a ‘balanced’ education is no longer sufficient. Instead, students need an ‘integrated’ approach to education. Specialization in one field must be accompanied by the ability to collaborate with specialists in other fields. Innovative ideas occur more and more at disciplinary intersections, and Union graduates must be prepared to engage in this kind of collaboration.”

To achieve these stated goals, Union offers an integrated education that takes its long-time commitment to the liberal arts and engineering into the 21st century. This approach makes Union a magnet for students with primary interests in the arts, humanities, and social sciences who understand the importance of being scientifically and technologically literate. It also makes it a college of choice for students who have a primary interest in science, engineering, and technology who know that their ability to excel in the real world depends on their being critical, broad-minded, and informed.

Building on its history of innovation in education, Union designed its undergraduate program around one of its most distinctive features: being the first college to offer engineering (civil engineering in 1845), and that its curriculum has a variety of courses that is unusual among small colleges. The Freshman Preceptorial and the Sophomore Research Seminar are two major fixtures in Union’s undergraduate program. They are designed as venues to pursue innovative approaches in teaching, help the students think critically, improve their writing ability, investigate the intersection between the sciences, engineering, and the liberal arts, develop communication skills, and exchange ideas with a variety of students from various backgrounds and interests.

IMPLEMENTATION

The Sophomore Research Seminar (SRS) is a recently developed and implemented program within Union’s undergraduate curriculum. Its main focus is to help the students learn through research. It is designed to encourage the students to use research as a tool to closely examine various factors that affect a certain behavior or that impact a certain decision. Faculty is invited to propose a theme for their SRS and to detail in their proposals how research is used to help the student achieve the goal of this course. Between 6 and 8 seminars are run simultaneously during each of Union’s three-term system. Faculty contributed to the development of these seminars is from many departments with those from the liberal arts and humanities constituting the overwhelming majority. After making the subjects of these seminars known, the students are given a form listing all SRS subjects. In this form, students express their preference for the subject of their seminar from the available list. In ranking their preference, students make their priorities known. According to unofficial statistics, it is possible to satisfy the student’s first wish in almost 80% of the cases.

The SRS developed by the writer was of very special nature in the sense that it included a technical lab in which students were expected to do a weekly lab exercise using fairly advanced software that many students were unfamiliar with. This was the only SRS offered with a lab component. The basic premise of this SRS revolved around a theme that used examples of constructed facilities to illustrate the technical aspect of the design together with the non-technical factors that have an impact on how the final design is developed. Some of the non-technical aspects that affect the design of constructed facilities are political, economical, budgetary, historical, environmental, climatic, public sentiment and perception, cultural, and...
social factors. In developing a design for a project, each of the above factors exerts certain impact on the final design. The extent of this impact may be minor but it can also be major. It is ultimately the responsibility of the design team to reconcile various viewpoints and listen to all expressed concerns and to attempt to incorporate features that will make the project acceptable to all, or at least a majority, of those that will be served by the project. This is no easy task and requires significant skill to accomplish. Competing opinions, especially those expressed with great passion, are seldom easy to fully accommodate. Furthermore, in many situations, the only way to reach a successful conclusion for the project, a spirit of cooperation between affected constituencies must exist. In absence of this, competing viewpoints may not find common ground for agreement, which may result in prolonged delays or even total disruption of the project.

Constructed facilities are used as examples in this SRS because they are daily encounters in people’s lives. Houses, offices, schools, hospitals, roads, bridges, airports, houses of worship, and sport, entertainment, and shopping complexes are some of the many examples of structures that people use and expect them to perform their intended functions smoothly. Structures can only perform their functions when their design involves the consideration of all the factors that may closely or remotely affect their intended in-service purpose.

History is rich with examples of structures that, in addition to their complex engineering, the wrangling about their construction involved a significant debate about non-engineering issues. Giant structures such as cable bridges, dams, towers, skyscrapers, domes, arches, tunnels, and oil rigs are laden with controversy. Engineering could be a tremendous design undertaking to put together such massive structures, but in reality this is the easy part of it. Because engineers do not operate in a vacuum, and because their conceived technical designs must gain the acceptance of a widely diverse public, and regulatory and financing bodies, they must be receptive to conflicting points of view, and willing to alter their designs to meet many competing criteria. The art of finding a common ground and reaching a compromise regarding hotly contested issues is one of the important attributes designers need to possess.

This course, entitled Artistic Engineering, explores some of the most complicated structures ever built and the engineering and non-engineering challenges that accompanied their planning and construction. After addressing the historical aspect of a given structure, students use a computer-based platform (SolidWorks software) to virtually build a model of that structure. This process is similar to solving a jigsaw puzzle. The major highlight of this approach is its hi-tech nature. In this exercise students are given pre-made computer models that constitute the individual components of the entire structure, and be given a roadmap showing how to assemble these pieces to build the entire structure. Once assembled, the model is possible to view in three dimensions, rotate, see-through, and manipulate to project in any desired profile. In addition to the weekly lab exercise, students are required to do a weekly assignment in which they select a structure of their choice and report on the non-technical aspects that impacted its design then virtually build the structure using the SolidWorks software package. In their final project, students are given the opportunity to do similar research on a structure of their choice where the scope and sophistication of the selected structure is expected to be considerable.

The required reading in this course is a book by Petroski (1) on the adventures resulting from pushing the limits of engineering design. The writer also compiled some case studies of lessons learned from failures of structures (2).

FORMIDABLE CHALLENGES
There have been a number of challenges faced in the first offering of the above-detailed SRS:

1. The students in this course were equally divided between engineering and non-engineering majors. Engineering students were mainly mechanical and electrical engineering majors. Non-engineering
students were from six different departments including computer science. This very diverse student body made it very difficult to appeal to their many different tastes and interests. Highly technical subjects are usually of great interest to the engineers but of little interest to the non-engineers. The opposite is true for non-technical subjects. This is a situation where the instructor needs to strike a balance between the technical and non-technical subjects to keep all interested. This stressful situation eased progressively week after week but one can still notice that some of the addressed topics were outside “the comfort zone” of some students due to the lack of familiarity with the subject being discussed.

2. Almost all the students in the class never had exposure or used SolidWorks software before that course. This necessitated a lengthy and steep learning curve to make the students familiar with what they were expected to learn and do. The learning curve was steepest for non-engineering students who had little or no background in operating such advanced software and with limited familiarity with the use of 3-D space drawings and visualization. This was a source of frustration that strained many students and required a huge commitment on the part of the instructor to provide help for many hours beyond the time allotted for the class. Although the expectation was that the burden would ease with the students acquiring greater skill in operating the software, this did not materialize because the assigned tasks became more complex with every new assignment.

3. Teaming engineering and non-engineering students for their final project required understanding on both parties of the role each could play in making proper contributions to reach a successful conclusion. Oftentimes moments of friction developed because each student in the team viewed their role and contribution as more vital than the contribution of the other party. The instructor had to stress many times the importance of appreciating each member’s contribution to reach a successful conclusion for the project.

Figure 1. The Brooklyn Bridge, New York City, New York (Produced with SolidWorks).
The writer wishes to emphasize that, despite all these challenges, the experience gained from teaching this course and from dealing with an audience, half of whom at least, of different mindset was extremely rewarding. Unlike any other course, it was evident that the interests and the style of learning differ significantly between engineering and non-engineering students. It is also worth noting that students’ initial mindset and their willingness, or unwillingness, to “open up” to new methods of teaching and learning can actually make or break the course. Fortunately, in this present course students were receptive to the idea that learning about subjects that fall outside of what they perceived to be their main circle of interest was not a waste of time after all. It may have taken them serious effort to do it but they greatly appreciated the skill they gained, the acquired ability to think critically, and the role others played to ensure a smoothly functioning society. These views were expressed in the official course evaluation.

**COURSE THEMES**

In selecting the projects presented to the students in this course, it was essential to consider three important factors. The first is that the structure should be impressive in nature and a masterpiece of engineering. The second is that the planning and design of the structure involved the consideration of many non-technical factors such as economical, environmental, political, historical, cultural, and budgetary. The third factor is that the project was controversial and, at the time of conception was subjected to significant public scrutiny. Under these circumstances, students could appreciate the role the engineers played in meeting all requirements and harmonizing conflicting viewpoints to reach a successful conclusion for the project.

*Figure 2. The Sunshine Skyway Bridge, Tampa, Florida (Produced with SolidWorks).*

**Suspension Bridges**

- Suspension bridges are very sophisticated structures. Cables are used to suspend the bridge deck from bridge towers. The study of the stability of a suspension bridge is very complex. The stability of these
bridges as they undergo construction is even more complex. The selected project addressed in this theme is the Brooklyn Bridge (Figure 1).

**Cable-Stayed Bridges**
- Cable-stayed bridges adopt an innovative technique to achieve stability. Cables are used to suspend the bridge deck from the main towers of the bridge. These cables transmit the loads to the towers that subsequently transmit it to the foundation. Bridge deck is usually made of segments. Each segment of the deck relies on at least a pair of cables to transmit its load to the tower. The operation of attaching the deck to bridge towers is a delicate one and requires balance because the loads on either side of the tower are usually almost identical. This is one of the major features of equilibrium in these bridges. The Sunshine Skyway Bridge, Tampa, Florida, is selected as an example of cable-stayed bridges (Figure 2).

![Figure 3. The CN Tower, Toronto (Produced with SolidWorks).](image1)

![Figure 4. The Statfjord B Oil Platform, Norway (Produced with SolidWorks).](image2)
**Towers**

- Towers are lightweight, tall structures usually anchored to the ground to prevent overturning and the impact of severe wind. The degree of sophistication of the anchoring system depends on the height and the weight of the structure. The method used in the construction of the tower depends on the materials used in construction. The selected tower addressed in this theme is the CN Tower in Toronto, Ontario, Canada (Figure 3). This tower is the highest freestanding structure in the world.

![Figure 5. The Superdome, New Orleans, Louisiana (Produced with SolidWorks).](image)

**Sea Platforms**

- Sea Platforms are used extensively in oil exploration and production. These platforms could be floating or anchored to the seabed. In either case, the construction of these structures constitute an unparalleled challenge due to factors that are extremely difficult to cope with such as water current and tide, in addition to strong winds. Engineers have been successful in devising innovative methods for offshore construction. The selected project addressed in this theme is the Statfjord B oil platform, Norway (Figure 4).

**Domes and Shells**

- Stadiums, houses of worship, sport and entertainment complexes are examples of structures constructed with a roof formed as a dome or as a shell. The design of domes and shells is one of the most complicated engineering tasks. Domes or shells are thin structures that cover large area with a considerable span. The segmental construction of these structural elements requires very extensive planning and sophisticated scaffolding systems. Every precaution is taken to ensure that these structures do not deform while they are under construction. Any deformation may compromise their safety. An excellent example of such structures is the Superdome, New Orleans, Louisiana (Figure 5).

**Dams**

- Dams are huge structures built across rivers to basically control the flow in the waterway. They are used to regulate water and/or for power generation. The river will have to be diverted to make the construction of the dam possible. In some cases a temporary structure (cofferdam) must be built to provide a dry zone for the permanent structure (the dam) while being constructed. The stakes are usually high in projects of this nature because the amount of water held by the temporary structure could cause a very destructive damage to communities along the river path. Hoover Dam, Nevada, is covered in detail in this theme (Figure 6).

**Tunnels**

- Tunnels are structures that require high engineering skill in design and construction. There are many great examples of underground and under water tunnels. The Channel Tunnel that links France and England is probably the most famous example of tunnels. The tunnel’s conceptual idea emerged
several centuries ago. There were always problems that prevented these ideas from being executed. The history and factors that affected the design and construction of the Channel Tunnel are selected as the subject of this theme (Figure 7).

Figure 6. The Hoover Dam, Nevada (Produced with SolidWorks).

PROJECT ARTNEERING
Project Artneering gives the students the opportunity to put into practice the knowledge gained in this course. The project entails the design of parts and assemblies. Students are not confined to selecting any specific type of structure. Students are divided to teams of two partners, an engineer and a non-engineer. Half way into the term each team is required to submit a progress report that includes the name and a brief description of the project, sketches of the intended structure, implemented steps toward the design, and anticipated final outcome. Project submittals includes SolidWorks drawings of individual components of the project, an assembly showing all components of the project, and views, and a document detailing all engineering and non-engineering aspects of the project (this may include relevant photos, figures, charts, graphs, tables, etc.).

Project grading criteria placed equal weight on the level of sophistication of design, practicality and functionality of design, accuracy and completeness of drawings, level of detail in presentation of components, and oral presentation.
STUDENT PROJECTS
Students demonstrated their interest in the subject of the course and their newly acquired skill in using SolidWorks in their final projects. Their selection of highly complex structures with great technical and non-technical features illustrated that they embraced the concept the course attempted to convey. The following are examples of projects students did in this course. Figure 8 shows the Sydney Opera House, Australia and Figure 9 shows the University of Phoenix Stadium, Arizona. The level of detail and the meticulousness in producing the 3D models of these structures are clearly evident. The oral presentations were equally impressive. It is of interest to note that both the students and the instructor took a lot of pride in these final projects.

BIBLIOGRAPHY

BIOGRAPHY
Ashraf M. Ghaly: Professor of Engineering, Union College, Schenectady, NY. Published over 250 papers, technical notes, and reports. Supervised over 50 research studies. Registered PE in NYS. ASCE Fellow and Member of the Chi-Epsilon Civil Engineering Honor Society.
Figure 8. The Sydney Opera House, Australia (Produced with SolidWorks).

Figure 9. The University of Phoenix Stadium, Arizona (Produced with SolidWorks).