AC 2011-2484: EMPLOYING ENGINEERING DESIGN TOOLS FOR DESIGNING/REDESIGNING OF COURSES

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Employing Engineering Design Tools for Designing/Redesigning of Courses

Introduction

As is the case in many fields of study, the importance and focus on certain topics changes over time. Changes in priorities can shift due to the availability of new technologies or any number of influences caused by political, social, or economic pressures. Over time, courses that are offered at universities shift accordingly to accommodate the need for new knowledge and depth of expertise. For example, the demand for expertise in the fields of geo-mechanics and geo-engineering emphasizing insitu measurements and data collection has increased over time due to growth in energy demand, enhanced production targets and more stringent regulations related to environmental control and sustainability issues. While Mining Engineering Department at Virginia Tech has a course *Insitu Measurements and Monitoring in Rock Engineering*, this course has not been offered since 1992. . Rather than creating a new course from scratch, including the lengthy process of approvals through multiple department, college, and university levels, an update/redesign of content and materials of this important field-oriented course in geo-mechanics was viewed as advantageous.

Developing a new course or redesigning an existing one, consists of several iterative processes including information collection, definition of learning outcomes in the form of competence and abilities desired, development of course content to achieve these outcomes [1], proper utilization of available data and resources, development of assessment criteria and student feedback. "It is a continuous process that starts with course planning, continues with lesson design and delivery, moves through student assessment and grading to conclude with course evaluation and revision"[2]. Several aspects of course design process are available in literature [3-5]. The process of course designing and update is a non-trivial task. It requires effective organization of different tasks, coordination of efforts and involves extensive decision making about the way course will be taught[5] to achieve desired outcomes.

This paper describes how engineering design process and methods, traditionally limited to the design of products and systems, can be applied to the design/redesign/update of courses. The redesigning of the course *Insitu Measurements and Monitoring in Rock Engineering* is used to highlight the benefits of using engineering design and planning tools such as SWOT Analysis, the House of Quality (HOQ), decision matrices, Gantt charts, and more. Similar to engineering design applications, these tools facilitate the course design/redesign process with steps such as planning, scheduling, alternatives selection, options evaluation and decision support in designing, developing, organization and structure of the course and materials.

Objectives

The main objective was to make the redesigned course more effective and learner centered. To achieve this, there must be a positive correlation and interaction between course components, learning objectives, activities and assessments. Learning objectives would need to be mapped to desired learning outcomes. While designing/updating, the focus remained on learners with the following questions in mind:

- What will students be able to do after the course that they cannot do now?
- What activities facilitate the student learning process?
- How will students demonstrate their knowledge and learning?

In order to answer above questions we identified the following objectives:

- to design a multidisciplinary course
- to enhance learner centered approach
- to provide up-to-date course material
- coherence in course content and materials
- to increase professional development
- applicability of course
- to improve quality and better marketing opportunities

Methodology:

The methodology was aimed to achieve the defined objectives as effectively and efficiently as possible by applying engineering design methods and tools. The sections that follow provide details of the main tools used in this process.

SWOT Analysis

The first step was to start the process with a SWOT Analysis. SWOT stands for strengths, weaknesses, opportunities and threats. It is a strategic planning tool[6] and is applied commonly in business management but can be used to evaluate single projects[7]. Its use is common in several disciplines[8-12] and has applications as a decision support tool[13]. It supports extraction of factors for analysis[10] and the development of strategic action plans [6, 9]. However, SWOT analysis requires definition of a clear objective before its application otherwise, it may not serve the purpose and may harm the performance [14-16] by giving a false sense of assurance and reducing the range of strategies to be considered.

The tool was employed to evaluate the pros and cons of redesigning the Insitu Measurements and Monitoring in Rock Engineering course and to assess whether the benefits of this effort were worthwhile. The SWOT Analysis usually consists of a table or chart having four quadrants. Each quadrant represents one of the SWOT elements. In these quadrants the potential strengths, weaknesses, opportunities and threats to the project are entered and then the strengths versus weakness and opportunities versus threat are weighed. Based on the net outcome of each SWOT element, the decision to either go with the project or look for an alternative is made.

As shown in Table 1, the SWOT analysis indicated that this course had potential for updating by pointing that strengths and opportunities for updating this course were more prominent than the threats and weaknesses. One of the major threats identified during SWOT analysis was the requirement of frequent field trips planned for the course. However, this was resolved by deciding that instead of going on frequent field visits, the students could solve case studies and practical problems assigned as part of in-class or take-home exercises. The SWOT analysis helped a lot in deciding the course content, teaching methodology, selection of related material and assessment criteria by keeping a focus on overcoming the weaknesses and threats and incorporating strategies to improve strengths and opportunities.

Table1: SWOT Analysis

SWOT Analysis	
Design Organization: ENGE-5024	**Date:** September 17
Topic Of SWOT Analysis: Explore the Potential for modifying a graduate level course *(Insitu Measurements and Monitoring in Rock Engineering)*	
Strengths: • Mining Engineering department at Virginia Tech since 1992 has not offered this course. Thus by redesigning the course, department will be able to offer an important course. • Owing to the multidisciplinary nature of the course, it will attract graduate students not only from mining department but also from other departments such as civil, earth sciences architecture etc. • There is a lot of improvement in the field of Rock Engineering & Rock Mechanics, so the new course will have all the up-to-date knowledge about the field. • The course demands frequent field tours due to applied nature of the course, thus helps to bridge the gap between theory & practice. • An experienced teacher, who is considered an authority in this field offer the course, thus attracting field engineers working on tunnels and rock slopes. • This is an already approved course and included in the course catalog, thus reducing time for approval process. • This course has already defined learning objectives and contents, thus the only requirement is to update and organize these contents with some additions. • It is an opportunity to make this course learner centered.	**Weaknesses:** • This is a graduate level course and will not attract under graduate engineering students. • It requires frequent field tours for experimentation & observational purpose. • For laboratory it requires all new and expensive instrument such as LVDTs, tilt meters, extensometers, etc • Experiment related to this subject are time consuming and relatively difficult to perform.
Opportunities: • This course may help increasing collaboration of mining department with industry. • If there is good feedback by the students of other departments regarding the multidisciplinary nature of the course then in future mining department may introduce more courses of this nature.	**Threats:** • Extensive field work/tours may upset students. • Laboratory Facilities may be limited. • Expensive instruments required
Team member: Zeshan Hyder	**Prepared by:** Zeshan & Zulfiqar
Team member: Zulfiqar Ali	**Checked by :** Dr. Richard Goff, Dr. Janis Terpenny
Designed by: Professor David G., The Mechanical Design Process (4rth Edition)	

Gantt chart

After establishing through SWOT analysis that redesigning was worthwhile, the next step was to develop requirements. This involved the compilation of data and information relevant to the course, selection of updates required for this redesign, review of previous course content, measure of course content expectations, revision of enhancements in related technology and developments in the materials and appraisal of students' needs and course level.

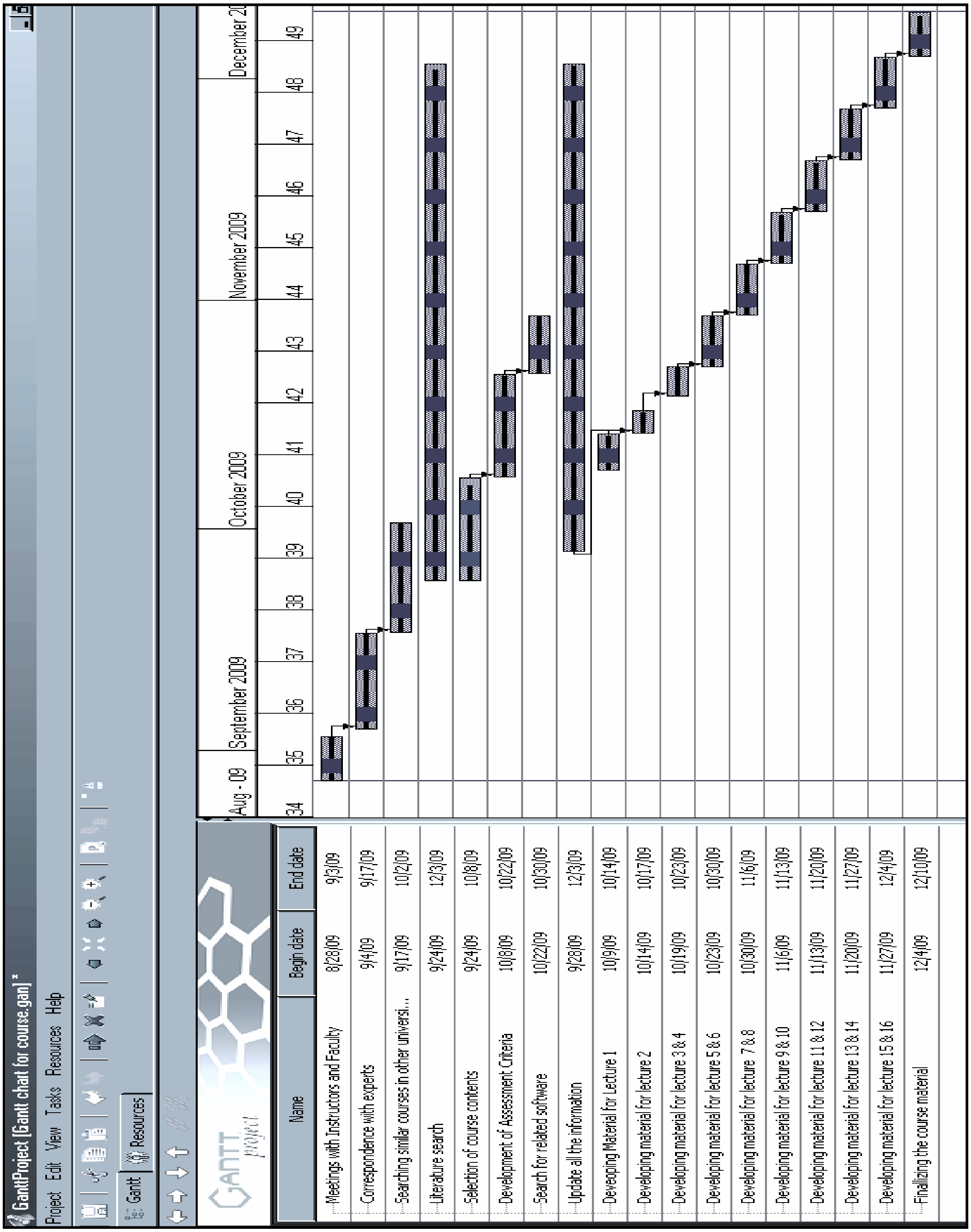
In order to organize our efforts and allocate time to different tasks a Gantt chart was prepared. A Gantt chart is a tool used to organize, schedule and allocate time for different tasks. It is a horizontal bar chart, developed by Henry Gantt in the USA for product/project scheduling at the Frankford Arsenal in 1917 and is still widely used in almost unaltered form[17]. It helps in defining the start and end date of any project/task. It also helps in the reduction of idol time by establishing a system to keep track of progress and improving coordination between different tasks, thus making a process more efficient. It is very effective in managing large projects [18-20]. There are several specialized software tools available that help in developing Gantt charts like Microsoft project [18, 21] or an Excel™ spreadsheet may be used for this purpose[22] .

The Gantt chart helped in dividing the work into different tasks, allocating time for each task and establishing dependency relationships between different tasks. It also helped in having a focus on the actual progress made against the allocated time for individual tasks. For this project, there was duration of 16 weeks. The first week started with consultations with faculty advisors and the instructor who had taught this course earlier. In this week, available data and previous course content were collected from the instructor, the SWOT analysis was performed, and the Gantt chart was prepared. In the next week, there were meetings with the advisors where the SWOT analysis and Gantt chart were discussed and further courses of action were specified. Experts in this field including teachers, instructors, field engineers and consultants were then consulted to give their opinion about the development of this course and updates that might be included in this redesign. The further tasks were as follows:

- Regular meetings with instructors to decide course objectives, teaching methods, finalizing course contents, assessment criteria and in-class assignments and exams
- Insight from faculty
- Search for similar courses in other competitive institutes
- Literature review for the subject being redesigned
- Web searches for updates and materials

These entries were put in the Gantt chart in the form of bars extending from start date to end date. A smaller bar in the middle indicated the percentage of the task completed. Small arrows showed the dependency relations between the end and start date of different tasks. Development of the material for each individual lecture took about one week for each lecture with literature search and information update running throughout the project time. Table 2 shows the Gantt chart developed for this project.

Table 2: Gantt chart



Name	Begin date	End date
Meetings with Instructors and Faculty	8/28/09	9/3/09
Correspondence with experts	9/4/09	9/17/09
Searching similar courses in other universi...	9/17/09	10/2/09
Literature search	9/24/09	12/3/09
Selection of course contents	9/24/09	10/8/09
Development of Assessment Criteria	10/8/09	10/22/09
Search for related software	10/22/09	10/30/09
Update all the information	9/28/09	12/3/09
Deveoping Material for Lecture 1	10/9/09	10/14/09
Developing material for lecture 2	10/14/09	10/17/09
Developing material for lecture 3 & 4	10/19/09	10/23/09
Developing material for lecture 5 & 6	10/23/09	10/30/09
Developing material for lecture 7 & 8	10/30/09	11/6/09
Developing material for lecture 9 & 10	11/6/09	11/13/09
Developing material for lecture 11 & 12	11/13/09	11/20/09
Developing material for lecture 13 & 14	11/20/09	11/27/09
Developing material for lecture 15 & 16	11/27/09	12/4/09
Finalizing the course material	12/4/09	12/10/09

House of Quality

The House of Quality (HOQ) is a matrix used in the Quality Function Deployment (QFD) method and is an internationally accepted technique[23]. It has very common application in engineering design to incorporate the needs, desires and wants of the customers in technical design to increase the customer satisfaction[24, 25]. The main idea behind use of HOQ is the belief that the design should reflect customer's desires[26]. In case of educational settings, the customers are students [27]. The house of quality was used in the course redesign to specify learning objectives and strategies to achieve these objectives.

HOQ has the structure of a table with "Whats" as the labels on the left rows and "Hows" across the top in columns. There is a roof above the table in the form of a diagonal matrix of "Hows vs. Hows" and the body of the house is a matrix of "Whats vs. Hows". Indicators fill these matrices according to the interaction of the specific item, i.e., whether a strong positive, a strong negative, or somewhere in between[28]. *The Mechanical Design Process* by David G Ullman illustrates QFD and HOQ in detail and was an excellent source utilized in this project tool[28].

Instead of using the whole template/table of House of Quality, Table 3 shows a simplified version utilized in the course redesign. It helped in identifying potential students from different engineering disciplines, their requirements and developing the course contents that matched the desired requirements. The rows of this table include desired objectives and abilities expected from students and columns indicate the strategies to achieve these outcomes. The indicators show qualitative relationships between columns and rows. For the sake of simplicity, only two indicators were used in identifying strong or moderate relationships between desires and how these might be achieved.

Decision Matrix

A decision matrix helped in the selection of contents, learning activities, teaching methods, materials and media appropriate and relevant to the goals and objectives of the course. This tool helps in prioritizing a list of options by eliminating irrelevant and unnecessary options. There are several types of decision matrices in use and each can be utilized for any project with simple adjustments [29-31].

In its simplest form, this is usually a table in which the options are listed in the rows and the attributes are listed in the columns. These options are weighed against desired attributes or objectives based on a scale usually ranging from 1 to 10. The selection of scale however is arbitrary and may be either qualitative (e.g. most relevant, relevant, not relevant) or quantitative with a scale defined by the creator. In the case of the course redesign, course contents, assignments, in class or take home exams, software selection, guest lectures and field trips were evaluated based on this simple matrix. Table 4 shows a sample of the decision matrix for assignment selection. The scale has a range between 1 and 10; with 10 being the most suitable or relevant and 1 being the least suitable or irrelevant. The values in each box represent the average of the numbers assigned by each participant to that option based on the objective or attribute.

Table 3: HOQ

			HOW														
			Case Studies	Field Tours	Engineering Problems	Class Exercises	Literature Review	Research Papers	Field Problems	Images	Simulations	Teacher's Expertise	Audio Visaul Aids	Presentation of material	Class Room	No. of Students	Department Ranking
Direction of Improvement																	
Units																	
WHAT	Contents	Relevance			✲									✲			
		Applied	✲														
		Up-to-date		○			✲		✲								
		Coherence												✲			
		Quality	○			✲				✲			✲			✲	
	Objective	Learning	○								✲						
		Expertise		✲								✲					
		Self-Confidence		✲							✲						
		State of the art knowledge						✲									
		Better Understanding	✲		○					✲			✲				
	Applicability	Better Market			✲												
		Job Opportunity		○													✲
		Research Options		✲				✲									
		Professionalism			✲							✲					
		Multidisciplinary		○										✲			

○ Strong Relationship
✲ Moderate Relationship

Table 4: Decision Matrix for Assignment Selection

Assignments	Time consumed	Learner centered	Field expertise	Hand on practice	Coordination & Interaction	Educational value	Self confidence	Problem solving ability
In-class	3	4	4	2	3	4	5	3
Take-home	9	8	9	6	4	8	7	9
Oral	5	7	9	6	3	7	8	8
Filed trip	2	7	10	9	8	9	7	5
Open book	8	8	7	3	3	5	5	5
Closed book	4	4	4	2	2	5	4	5
Group	8	8	9	5	9	7	5	8
Individual	4	8	4	6	4	5	6	6

Design Iterations

As in the engineering design process, the course redesign was an iterative process with each iteration bringing new ideas and changes. Initially the course had redundancies, lengthy content, time-consuming assignments and material that was not within the scope of the course. Every iteration helped in developing a course that was concise, to the point, without unnecessary lengthy theories and gave greater emphasis to practical background, concept development, application and standard methodology (all desired characteristics for course customers, i.e., faculty and students).

Final draft for the course had the following attributes:

- Clearly Defined Parts
- Distinction Among Parts
- Focused
- Multidisciplinary
- Learner's Centered
- One Semester Course
- Field tours replaced with the case histories and take home assignments
- exams replaced with field related projects
- Incorporated New Technological Developments
- Concept Building by Relevant Hands-on Assignments
- Emphasis on Case Studies
- More Focus on Data Interpretation
- Well Defined Evaluation/Assessment
- More Weight on Class/Group Assignments
- Software (demonstration purpose only) proposed

Evaluation and Assessment of Student Learning

In order to make this course interactive for students and to follow a learner-centered approach, exams were replaced with take home field related group assignments. Oral presentations and group discussions were encouraged to increase student participation. The assignments were suggested to be completed in groups to improve teamwork, coordination and mutual interaction. Grades were based on student participation and learning with more weight given for hands-on exercises. The course emphasized case studies and solution of practical problems rather than a more traditional approach that focuses on lecture delivery by the instructor, textbook problem sets, and tests.

Conclusions and Future Work

Designing or redesigning a course is a lengthy process and consists of several time consuming steps. The continuous advancement of technological developments requires that all technical courses be revised regularly. Use of design tools like SWOT Analysis, House of Quality, Decision Matrix and Gantt chart can aid the course redesign process. In the case of the *Insitu Measurements and Monitoring in Rock Engineering* course, these tools made the effort more focused, organized and student oriented. Use of these tools made teamwork, conflict management and decision making an easy job. The approach put forward in this paper may be helpful and of interest to others planning to re-design/upgrade courses. Future work will investigate impacts on quality (i.e., student learning and motivation), reductions in development time and costs in greater depth and include a variety of course design/redesign projects.

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