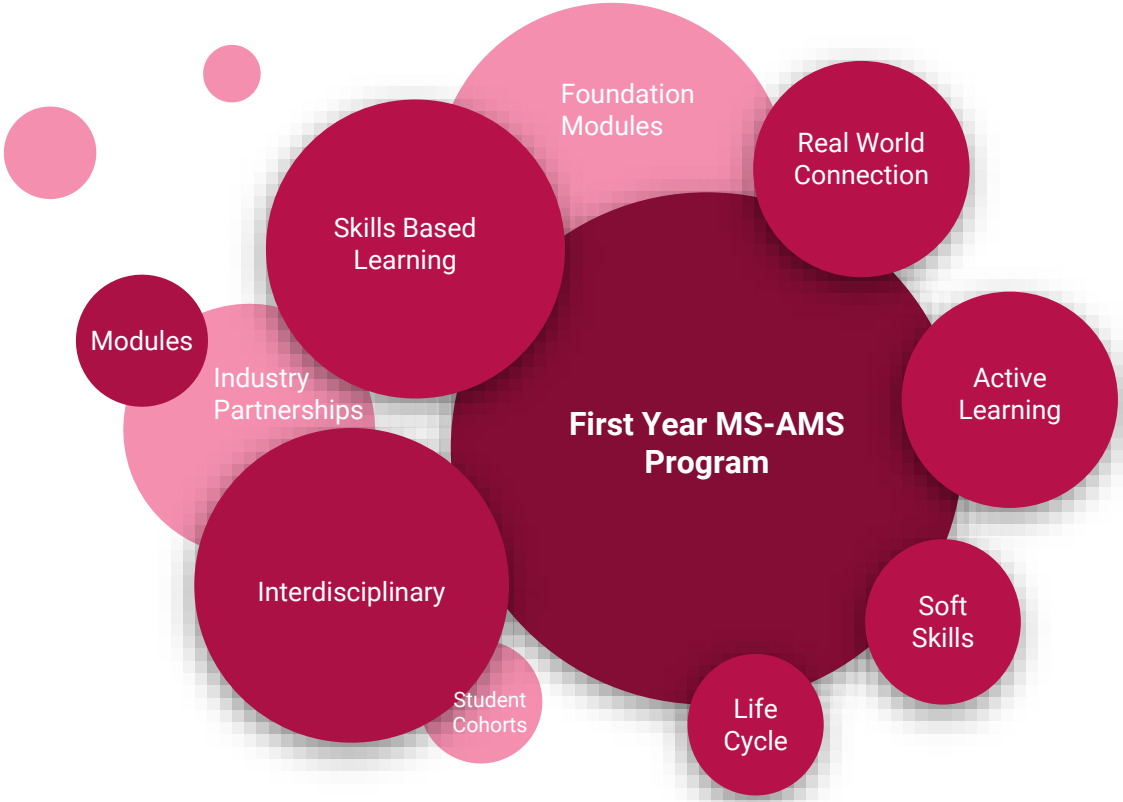
Pilot Course

Polymers and Composites for Materials Scientists

Dr. Robert Carlson and Dr. Gireesh Menta

Spring 2018

Pilot Program Goals



Subjects for the Pilot Course

http://greenblue.org/about/smm/

	SEMESTER I					SEMESTER II				
	AUG	SEP	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY
YEAR 1	Metals and Metal Alloys	Ceramics	Polymers		Final Project	Composite Materials		Paints/ Coatings	Material Degradation/ Recycling	Final Project
	Practical Training					Practical Training				

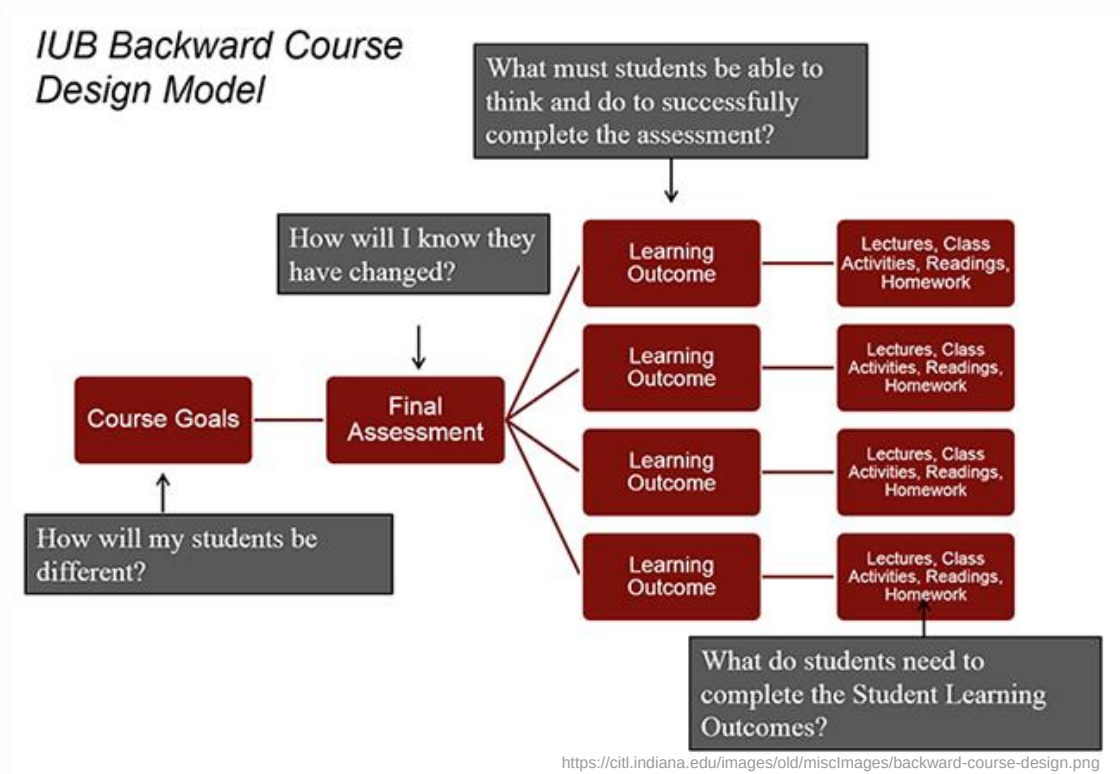
"Polymers and Composites for Materials Scientists"

Course Structure and Timeline

- Dr. Robert Carlson (Polymers)
- Dr. Gireesh Menta (Composites)

Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Subject	Short Course on Polymers			Materials			Design & Analysis					Manufacturing		Testing, Repair and Recycling	
			Labs						*Computer Labs*				*Labs*		

Developing Course Content



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Course Goals

After completing the course, students will be able to:

- Demonstrate similar level of understanding irrespective of their background or department
- Demonstrate understanding of materials, manufacturing and design of FRP composites
- Apply the knowledge and tools learned in the class to design and manufacture composites for a given application
- Express confidence in communicating and working with students from different backgrounds

Targeted Tools and Skills

- Knowledge of available fibers, forms and matrices
- Material selection based on customer and product specifications
- Manufacturing using hand lay-up, VARTM, Autoclave and Out of Autoclave
- Excel sheets to design layup configuration, composite thickness and estimating the resulting load capacity, strength and stiffness of the composite product

Goals and Final Assessment

Goals	Assessment
Demonstrate same level of understanding irrespective of their background	When the final results are compared, Chemistry students perform as good as engineering students, and viceversa
Industry readiness	Know how to handle prepregs, read data sheet and heat according to cure cycle
Demonstrate interdisciplinary skills	Chemistry students comfortable in communicating with engineering students and viceversa
Improved soft skills (presentation, team work etc.)	Practice group work and short presentations

Goals	Assessment
Demonstrate understanding of materials, manufacturing and design of FRP composites	For a given application, students can select proper fibers, matrix and specific manufacturing process
	Reasonably ready to manufacture a part using hand lay-up, VARTM, OOA or Filament Winding Process
	For a given application, students can produce optimum fiber lay-up configuration using excel sheet

Specific Learning Outcomes

For a given application, students can select proper fibers, matrix and specific manufacturing process

- Define composites (what are composites?)
- Identify the benefits of composite materials
- Why use composites? (when we have other matls?
- Identify the applications of composites in different fields
- Describe the differences between isotropic and anisotropic materials
- In what aspects are composites different from metals?
- Explain the roles/functions of fiber and matrix
- What are the mechanisms that provides composites their benefits?
- Explain failure mechanisms in composites and their tolerances
- What is the mechanism that provides composites with their benefits?
- List commonly used fibers and matrices
- Identify main aspects of different fibers and matrices
- List different forms in which fibers are available
- List different manufacturing techniques of thermoset and thermoplastic composites
- Identify the fundamental physics behind composite manufacturing process
- Identify common terminology in composite manufacturing process
- Describe typical defects found in composite manufacturing process and explain how these can be minimised

For a given application, students can produce optimum fiber lay-up configuration using excel sheet

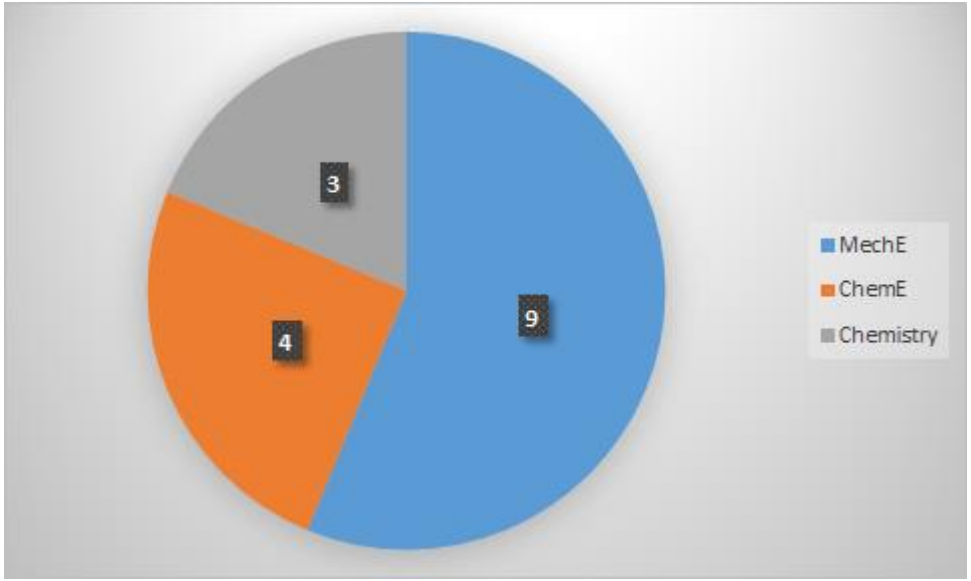
- Define lamina vs. laminate
- List elastic constants in a 2D lamina
- Apply Hooke's law to unidirectional composite
- Predict the properties of uni. composite using micromechanical approach
- List commonly used approaches for prediction of elastic constants
- Predict the properties using three approaches
- Outline stress-strain relations of uni. composite subjected to mehanical, thermal and moisture loads
- Explain bending/stretching, coupling and streching shear coupling in composite products
- Apply Hooke's law to laminate
- Apply Different failure criteria
- Demonstrate your knowledge by designing composite laminate for different applications

Class Activities

S.No.	Specific Learning Targets	Quizzes	In-class Discussions	Assignments	Projects
1	Define composites (what are composites?)				
2	Identify the benefits of composite materials				
3	Why use composites? (when we have other matls?				
4	Identify the applications of composites in different fields				
5	Describe the differences between isotropic and anisotropic materials				
6	In what aspects are composites different from metals?				
7	Explain the roles/functions of fiber and matrix				
8	What are the mechanisms that provides composites their benefits?				
9	Explain failure mechanisms in composites and their tolerances				
10	What is the mechanism that provides composites with their benefits?				
11	List commonly used fibers and matrices				
12	Identify main aspects of different fibers and matrices				
13	List different forms in which fibers are available				
14	List different manufacturing techniques of thermoset and thermoplastic composites				
15	Identify the fundamental physics behind composite manufacturing process				

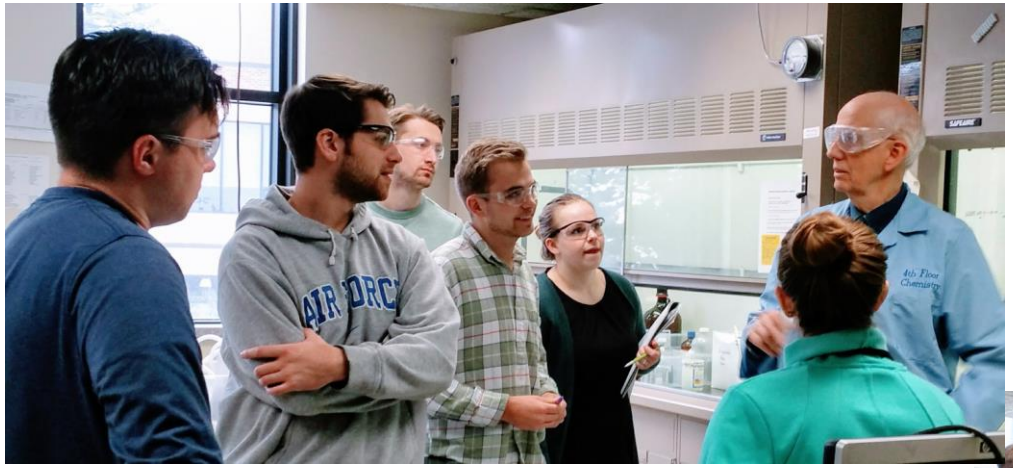
S.No.	Specific Learning Targets	Quizzes	In-class Discussions	Assignments	Projects
17	Describe typical defects found in composite manufacturing process and explain how these can be minimised				
18	Define lamina vs. laminate				
19	List elastic constants in a 2D lamina				
20	Apply Hooke's law to unidirectional composite				
21	Predict the properties of uni. composite using micromechanical approach				
22	List commonly used approaches for prediction of elastic constants				
23	Predict the properties using three approaches				
24	Outline stress-strain relations of uni. composite subjected to mehanical, thermal and moisture loads				
25	Explain bending/stretching, coupling and streching shear coupling in composite products				
26	Apply Hooke's law to laminate				
27	Apply Different failure criteria				
28	Demonstrate your knowledge by designing composite laminate for different applications				
29	Demonstrate by manufacturing 4 in. x 4 in. flat composite part using hand lay-up				
30	Demonstrate by manufacturing 4 in. x 4 in. flat panel using VARTM Process				
31	Demonstrate by manufacturing 4 in. x 4 in. flat panel using OOA Process				
32	Demonstrate by manufacturing a 6 in. long composite cylinder using filament winding process				
33	Demonstrate by manufacturing a dog bone shaped part using injection molding process				

Student Enrollment

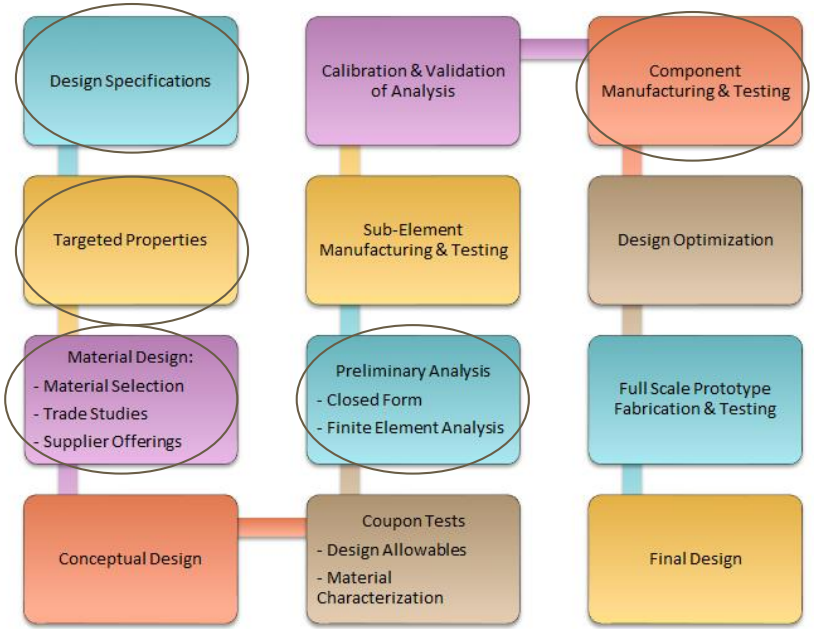


Class

Labs



Examples of Assignments



Building Block Approach to Final Product Delivery

Assignment 3

Name: _____ Due Date: 2/21/18

Each group has been assigned a specific part from a specific industry. For the assigned part, each group should suggest their top choices for fibers and resins. A group of three will suggest three fiber materials and three resin systems whereas a group of two will suggest two material systems. All three suggested options can be of the same material eg. Carbon or epoxy, but of different types/forms or from different suppliers etc. Should also include the rationale behind the selection (like properties, cost etc.) and the details of the suppliers (eg. Website links etc.). Since you neither have the product specification nor yet covered the manufacturing aspects, you can only make a best guess.

Group No.	Part	Industry
1	Truck bed	Automotive
2	Oxidizer tank for rockets	Space
3	Handle bars for dirt bikes	Racing
4	Small UAV	Aerospace
5	Combat helmet	Defense
6	Wind Turbine blades	Energy

Some useful resources:

1. https://www.compositesworld.com/suppliers
2. http://www.matweb.com/index.aspx
3. http://www.uscomposites.com/

Mathematics Involved in Design

$$\varepsilon_x = \frac{\partial u_0}{\partial x} - z\frac{\partial^2 w}{\partial x^2}$$

$$\varepsilon_y = \frac{\partial v_0}{\partial y} - z\frac{\partial^2 w}{\partial y^2}$$

$$\gamma_{xy} = \frac{\partial u_0}{\partial y} + \frac{\partial v_0}{\partial x} - 2z\frac{\partial^2 w}{\partial x \partial y}$$

$$\begin{Bmatrix} N_x \\ N_y \\ N_{xy} \\ M_x \\ M_y \\ M_{xy} \end{Bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} & B_{11} & B_{12} & B_{16} \\ A_{12} & A_{22} & A_{26} & B_{12} & B_{22} & B_{26} \\ A_{16} & A_{26} & A_{66} & B_{16} & B_{26} & B_{66} \\ B_{11} & B_{12} & B_{16} & D_{11} & D_{12} & D_{16} \\ B_{12} & B_{22} & B_{26} & D_{12} & D_{22} & D_{26} \\ B_{16} & B_{26} & B_{66} & D_{16} & D_{26} & D_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \\ \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix}$$

$$\begin{Bmatrix} \varepsilon^0 \\ \kappa \end{Bmatrix} = \begin{bmatrix} A' & B' \\ C' & D' \end{bmatrix} \begin{Bmatrix} N \\ M \end{Bmatrix}$$

where

$$[A'] = [A^*] - [B^*][D^*]^{-1}[C^*]$$

$$[B'] = [B^*][D^*]^{-1}$$

$$[C'] = -[D^*]^{-1}[C^*]$$

$$[D'] = [D^*]^{-1}$$

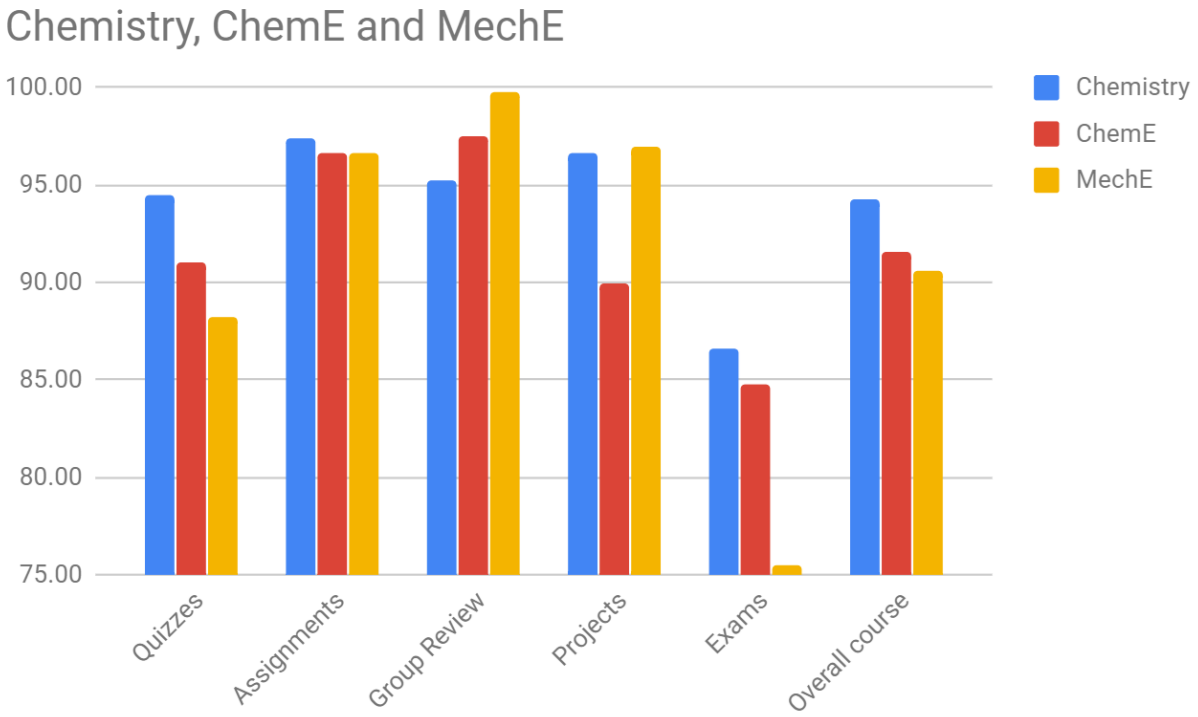
and

$$[A^*] = [A]^{-1}, \quad [B^*] = -[A]^{-1}[B]$$

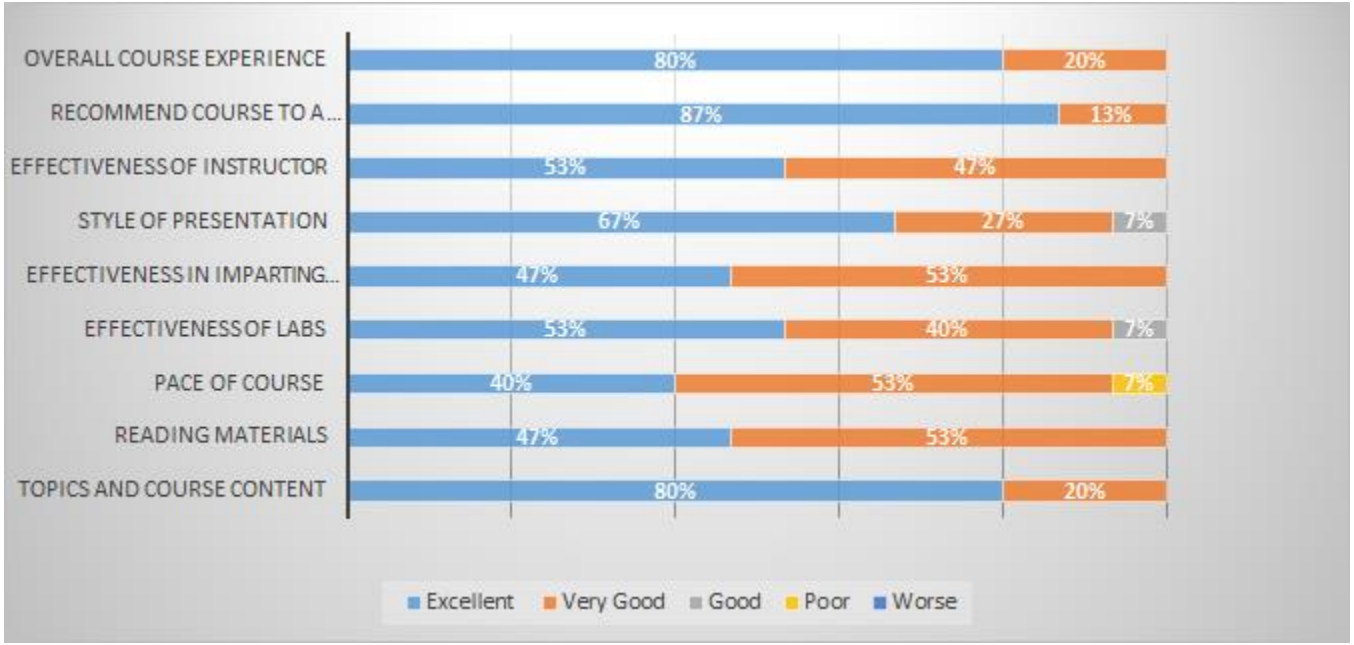
$$[C^*] = [B][A]^{-1}, \quad [D^*] = [D] - [B][A]^{-1}[B]$$

$$\begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}_k = \begin{bmatrix} \overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16} \\ \overline{Q}_{12} & \overline{Q}_{22} & \overline{Q}_{26} \\ \overline{Q}_{16} & \overline{Q}_{26} & \overline{Q}_{66} \end{bmatrix}_k \begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{Bmatrix} + z \begin{bmatrix} \overline{Q}_{11} & \overline{Q}_{12} & \overline{Q}_{16} \\ \overline{Q}_{12} & \overline{Q}_{22} & \overline{Q}_{26} \\ \overline{Q}_{16} & \overline{Q}_{26} & \overline{Q}_{66} \end{bmatrix} \begin{Bmatrix} \kappa_x \\ \kappa_y \\ \kappa_{xy} \end{Bmatrix}$$

Student Performance



Student Feedback



Student Comments on Going into Composites Industry

"I am confident to jump in and help with a composites project"

"I feel very confident"

"I feel confident that I have the background of design, analysis, manufacturing to be able to land a job in the field. I feel I have unique qualities (design spreadsheet) to help land the job and impress"

"I would feel very comfortable going into industry. I feel that I have the background to extend my knowledge quickly"

"I feel extremely Confident"

"Very effective. Applicable knowledge that is easily transferable to industry"

"I feel confident"

"I feel much confident for composites, resins and polymers"

Student Comments on Effectiveness of Course

"Very effective. Design section was extremely interesting and relevant"

"Very good, even the introduction of these topics and methods will help very much"

"This course did an excellent job instructing me as to how to design and manufacture composites"

"Very efficient"

"Quite effective"

"Very effective. Throughout the course, the instructor would give examples of industry techniques or information"

"It was a very helpful course"

After the Course

- Lightweight shoes
- Drones
- Composite bike
- Composite shelf
- 3D Printing
- Vacuum bagging for sensors (Research)

Conclusions

- Proposed framework is effective in bringing students from diverse background to relatively same level of knowledge
- Students demonstrated their tools and skills on selected industry problems/projects
- Significant progress was observed in student's ability to communicate with those from other backgrounds
- Student cohorts created a strong sense of community
- Overall, students strongly supported the proposed framework

Acknowledgements

- Julia Williams, Ass. Pro. & Dir. of Grad. Studies, College of Education & Human Services Professions
- MIE Department Staff/Students
  - Tracy Shaw
  - Darrell Anderson
  - GTA's
  - Senior Design Students (letting us use their makeshift oven)
  -

- Participated students of the class

THANK YOU