AC 2007-263: INDIVIDUAL PROJECT-BASED APPROACH TO DEVELOP RESEARCH APTITUDE IN MANUFACTURING ENGINEERING STUDENTS

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Individual Project-based Approach to Develop Research Aptitude in Manufacturing Engineering Students

Abstract

This paper chronicles experiences with individual research-paper projects in teaching a senior level course on Polymer Properties and Processing to manufacturing engineering majors. Polymer Properties and Processing is one of five elective courses in the area of processes. Students complete courses on 'Materials Engineering' and 'Materials Selection and Processes' prior to taking this course. The course exposes students to current trends in plastics and composites industry as a means to prepare them for graduate study. Accordingly, in this course rather than assigning team based projects, research paper topics were assigned on an individual basis. Thirty percent weight was given to this research activity.

Students were systematically prepared for taking up the research paper activity. Demonstrations were organized in the research laboratories in the Chemistry department pertaining to basic polymer characterization techniques. These techniques include GPC, TGA, and DMA. Three industrial visits were organized to expose students to injection molding, extrusion, and carbon-composite manufacturing processes. Students also viewed videos prepared by the 'Society of Manufacturing Engineers' in the areas of processing.

The instructor suggested a few important research topics. These topics included polymer nanocomposites; bio-based polymers and composites; and polymers in NVH applications. Students were also encouraged to bring their own topic ideas. Students were expected to refer handbooks, magazines, research articles, and web sources. They were encouraged to visit industry and research labs within and outside university. A minimum of 15 core technical references were expected from different sources. Students prepared a 10-12 page research paper and delivered a 10 minute presentation in front of the entire class. Two external evaluators with broad industrial experience were invited to assess the performance. Course evaluations revealed very promising results and provided concrete feedback. In fact, out of ten students, three have decided to pursue careers in composite materials. This paper details the pedagogy and the research paper activity.

Background

Manufacturing engineering is a relatively new and small program in the department (Refer Table 1). Our "hands-on", curriculum includes laboratory experiences in physics, chemistry, computer-aided design, manufacturing processes, RP, quality assurance, electronics, robotics, microelectronics manufacturing, simulation and computer integrated manufacturing. The manufacturing engineering program is scheduled to undergo ABET accreditation in Fall 2007. Companies such as Toyota, Northrup-Grumann, Boeing, National Instruments, etc. as manufacturing or process engineers have hired our graduates. We are in the process of collecting data pertaining to number of students enrolled for graduate studies, but this number is very small. Though our curriculum emphasizes "hands-on" and team based learning, it does little formally

by way of preparing students for graduate studies. Secondly, major thrust in the present manufacturing curriculum is towards metallic materials and processes. Majority of the courses assign team-based projects. Majors in manufacturing engineering have very limited knowledge of plastics and composites. The authors have identified the necessity of a course in the area of plastics and composites while teaching other courses such as Computer Aided Engineering[1]. The course TECH 4367 – Polymer Properties and Processing was offered for the first time in the department in Spring 2006. In this course rather than assigning team based projects, research paper topics were assigned on an individual basis. The research project was determined as a major learning tool. The students were systematically prepared for taking up this activity. Independent research activity develops research aptitude in early career, prepares students for graduate studies, develops independent thinking, and makes students responsible for their learning.

Table 1. Enrollment and number of graduates: Bachelors in Manufacturing Engineering

	2006	2005	2004	2003	2002	2001	2000
Enrollment	93	75	79	74	51	21	8
# Graduates	18	17	14	--	--	--	--

Manufacturing engineering majors are required to take two processes electives. This course is one of the five electives. Ten students enrolled for the course. Considering the total enrollment in manufacturing engineering department and fact that the course was offered for the first time, ten students is a good enrollment. Students had perquisite knowledge of 'Materials Engineering' and 'Materials Selection and Processes'. Topics in the course were selected such that they would help students in research paper. The topics in the course were selected from two different texts[2, 3] and are as follows:

- Polymer Materials – Molecular Structures, Microstructures, and Polymerization
- Mechanical, Chemical and Physical Properties
- Thermoplastics and Thermoset materials
- Plastics Manufacturing Processes: Extrusion, Injection Molding, Blow Molding, Thermoforming, and Compression Molding
- Polymer Matrix Composite (PMC)
- PMC Manufacturing Processes: Lay-up, Filament winding, Vacuum Bagging, and Pultrusion

Besides regular lectures, demonstrations in the area of polymer characterization and plant tours exhibiting major manufacturing processes were organized.

Teaching Schedule and Evaluation Methodology

This course was taught (Spring 2006) twice a week for one hour and fifteen minutes. The course was a blend of lectures, videos, plant tours, and research lab visits. Three plant tours and one research lab visit was organized. Ten videos were showed and discussed in the class.

The following polymer characterization techniques were demonstrated in the Polymer Chemistry lab. These techniques were explained in brief in the class prior to the visit.

- Dynamic Mechanical Analysis (DMA) for viscoelastic behavior of polymers

- Gel Permeation Chromatography (GPC) for evaluation of molecular weight
- Thermal Gravimetric Analysis (TGA) for evaluating composition

The three plant tours were organized in the local industry in San Marcos. Students were asked to write brief Plant Tour reportswith the following focus:

- Stellar Plastics[4] – injection molds and injection molding
- Flex-Tech Hose and Tubing Company[5] – extrusion
- C-Fan[6] – manufacturing of 'carbon/epoxy composite fan blades' for jet engines

For better understanding the following videos were showed in the class. These videos are prepared by the 'Society of Manufacturing Engineers'. Before showing a particular video the detailed notes pertaining to that video were circulated. Students were asked to read through these notes before watching videos. By this method students would watch video carefully and would not loose attention in writing notes.

- Plastics – 15 minutes
- Polymer Production Techniques – 21 minutes
- Plastics Injection Molding – 25 minutes
- Plastics Injection Molds – 28 minutes
- Plastics Extrusion Processes – 21 minutes
- Plastics Blow Molding – 24 minutes
- Plastics Machining and assembly – 28 minutes
- Composites Materials – 17 minutes
- Manual Lay-up and Spray Lay-up – 16 minutes
- Filament Winding – 17 minutes

Table 2 explains the schedule on weekly basis pertaining to teaching, plant tour, lab visit, and research paper activities. The students' performance in the course was assessed based on different data sources such as homework, plant tour reports, mid-term and final exam. Table 3 exhibits the student assessment statistics. Students were asked to fill out their assessment of course outcomes on a scale of 1 to 8. One being very strongly disagree and eight being very strongly agree. Table 4 displays excerpts of the course outcomes.

Table 2. Schedule of teaching, video, plant tours, and research paper on weekly basis

Lecture topics	Video	Plant tour	Research paper
Stage I- Polymer Properties and Characterization (week 1-3)			
1.Polymer materials – Molecular Structures, Microstructures, and Polymerization' 2. Mechanical, Chemical and Physical Properties' 3. Basics of polymer characterization: DMA, GPC, and TGA	1. Introduction to plastics	1. Research lab-demonstrations of DMA, GPC, and TGA	1. Introduction to research paper activity – in 3rd week
Stage II- Thermoplastics and Thermosets: Materials and Processing (Week 4-9)			
4. Commodity thermoplastics 5. Engineering thermoplastics 6. Thermosets 7. Injection molding 8. Extrusion 9. Blow molding 10. Plastics machining and assembly	2. Polymer Production Techniques 3. Plastics Injection Molding 4. Plastics Injection Molds 5. Plastics Extrusion 6. Plastics Blow Molding 7. Plastics machining and assembly	2. Stellar Plastics 3. Flex-Tech Hose and Tubing Company	1. Details about research paper activity –7th week 2. Topic finalization – in 8th week 3. Discussions on research paper resources and samples reports- 9th week
Stage III- Composite Materials: Processing and Characterization (Week 10-12)			
11. Composite materials, Basics 12. Constituent materials: properties and applications 13. Manual and spray layup 14. Vacuum infusion processes and detailed discussions on low cost vacuum assisted resin transfer molding (VARTM)	8.Composite materials 9.Manual layup and spray layup 10.Filament winding	4. C-Fan Company	4. First progress report due – 11th week
Stage IV- Research Paper Exam			
15. Review for final exam 16. Final report and presentation discussions 17. Research paper final exam	----------	----------	5. Second progress report due – 13th week 6. Final report and presentation due – 14th week

Table 3. Student assessment

Topic	Max	Ave	Std. Dev.	% Ave./Max	Data Source
Polymer materials – Chemistry	60	52.7	18.58	87.83	HW1-Q1-6
Mechanical Properties	50	48.4	3.10	96.80	HW2-Q1-5
Chemical and Physical Properties	30	23.7	8.67	79.00	Mid-termQ17-25
Thermoplastics materials – commodities and engineering	25	18.2	7.48	72.80	Mid-term Q6,7,16,27
Thermoset materials	16	12	4.47	75.00	Mid-term Q1-5
Extrusion	50	45.6	2.46	91.20	Plant tour report (Flex-Tech)
Injection Molding	50	47	4.83	94.00	Plant tour report (Stellar Plastics)
Blow Molding	10	8.8	1.80	88.00	Final Q31-34
Composite Materials, Basics	10	8.05	1.44	80.50	Final Q4-8
Composite Materials Calculations	10	6.95	3.62	69.50	Final Q9-11
Composite Lay-up Processes	10	8.9	1.29	89.00	Final Q12-15
Vacuum Bagging Processes	10	7.8	2.04	78.00	Final Q 16-19
Filament winding	10	8.2	2.86	82.00	Final Q 20-22
Research paper: Report	100	85.4	3.72	85.40	Research paper
Research paper: Presentation	50	33.2	11.88	66.40	Presentation

Table 4. Student learning outcomes

Topic	Max	Average	Std. Deviation
Polymer materials – Chemistry	8	6.50	0.53
Mechanical Properties	8	6.50	1.18
Chemical and Physical Properties	8	6.30	0.82
Thermoplastics materials – commodities and engineering	8	6.70	0.82
Thermoset materials	8	6.30	0.82
Extrusion	8	6.60	1.07
Injection Molding	8	6.60	0.97
Blow Molding	8	6.50	0.85
Thermoforming	8	6.00	1.05
Composite Materials, Basics	8	7.20	0.63
Composite Materials Calculations	8	6.90	0.57
Composite Lay-up Processes	8	7.00	0.82
Vacuum Bagging Processes	8	7.00	0.82
Filament winding	8	6.40	1.26

Plant Tours

Plant tours were regarded as a major learning source for the research paper activity. Students had opportunity to talk to researchers, engineers, and management persons to understand the importance of higher studies and research aptitude. All plants that were visited engage themselves in solving challenging problems and were not merely production shops.

Research Lab Visit: Institute of Environmental and Industrial Science[7] (IEIS)
IEIS at Texas State University has state-of-the art lab for polymer characterization consisting of DMA, TGA, and GPC. Students were demonstrated DMA, TGA, and GPC techniques. Also some of the current research activities in IEIS such as bullet-proof, self-healing polymers; polymer nanocomposites; and bio-based resins were discussed. Students were inspired by watching graduate students and researchers in action.

Plant Tour 1: Stellar Platics[4], Inc.
Stellar Plastics develops specialty injection molds for reputed firms such as Dell and Toyota. President and vice-president of the company accompanied the students during tour. They provided insights on designing with plastics components. Many challenging injection molds were exhibited. Stellar Plastics also engage in the regular production of injection molded parts. Students could watch entire cycle of part production on injection molding machines.

Plant Tour 2: Flex-Tech Hose and Tubing[5], Inc.,
Flex-Tech produces rigid and flexible tubes and pipes using extrusion process. Students had opportunity to understand entire extrusion system. They also had opportunity to see assembly of extrusion screw and how extrusion system is started at the beginning of production. There was also problem of 'melt fracture' and engineers at Flex-Tech explained the reasons and troubleshooting methodology. It was about three hour-long visit and students learned lot that couldn't be explained in regular lectures.

Plant tour 3: C-Fan Company[6]
C-Fan is created by GE Aircraft Engines and SNECMA, two leading aerospace companies to manufacture very high precision parts using advanced performance composites such as jet engine fan blades. Students received opportunity to watch prepreg cutting, mounting, autoclave, and post curing. At the end engineers at C-Fan showed short video explaining challenges that C-Fan meets in producing high precision components such as fan blades. This was most exciting plant tour and students were really charged with composites manufacturing.

Major Activities Related to Research Paper

Research Paper – Introduction
The brief explanation was made about the purpose of research paper; nature of work; and expectations in the 3rd week. At the end of 7th week, details of research paper activity were provided. By this time the students have amassed a good understanding of basic polymer chemistry, polymer characterization, thermoplastics and thermoset- properties and applications, and different manufacturing techniques. The document explaining purpose of research paper, format of first and second progress reports, format of final report, format of PowerPoint

presentation, and important due dates related to research paper was circulated. Also, few sample research papers were given so that students will have clear idea about this activity. It was not expected that the students would perform experiments and report their findings. It was expected that students would select a topic, which had current importance (such as Polymer nanocomposites). Later they will collect information from different sources such as handbooks, magazines, research articles, and web sources. They were also encouraged to visit the industry and research labs. They were expected to compile a 12-15 page research paper and deliver a 10 minutes presentation in front of entire class. It was expected that students would have at least 15 technical references from mixed sources. It was insisted that each paper must have Abstract, Introduction, Conclusions and Future Scope, and References. The students were asked to bring their own topics in the following week. The instructor suggested few topics such as polymer nanocomposites; bio-based polymers and composites; and polymers in NVH applications.

Research Paper – Topic Finalization

This week research paper topics were finalized. Many students brought their own topics and few selected topics suggested by the instructor. The final topics were as follows:

- FRP Reinforced Concrete
- Phenolic Resins
- Recycling of Plastics Waste
- Polymer Nanocomposites
- Carbon Fiber Reinforced Composites in Aerospace Applications
- Composites Materials in Automobile Applications
- Thermoplastics Composites
- Polymers in NVH (Noise, Vibration, and Harshness) Applications
- Bio-based Plastics and Composites
- Biocomposites: Plastics and Composites in Biomedical Applications

Students who had accepted jobs with Chrysler and Boeing were assigned topics 'Composites Materials in Automobile Applications' and 'Carbon Fiber Reinforced Composites in Aerospace Applications', respectively. All the above topics have current importance and good amount of literature is available. Students were asked to collect information from all sources. Two progress reports were asked one after two weeks and other after four weeks from date of assignment of specific research paper topic.

Research Paper- Resources

In second lecture sources regarding research paper were discussed. The instructor had setup time with each student to discuss probable sources for literature review. The instructor shared handbooks[8-12], books, magazines, research papers, and personal contacts within and outside university. They were also advised to visit the instructor's web page listing important links related to composites[13].The magazines used were Composites Manufacturing, Composites Fabrication , High-Performance Composites , and Composites Technology .

The instructor insisted students to visit websites of National Composite Center -NCC[14] and Lightweight structures B. V., Netherlands [15]. These research organizations engage themselves in applied research. NCC has developed composites leaf springs, pickup truck beds, FRP bridge decks, and FRP temporary runways. Lightweight structures B.V. has developed composite

safety barrier, lighting columns, crash cones for truck, and truck trailers. Students were excited to see the enormous applications of composites in the real world.

Students were advised to go through database sources available on university's library website for finding related research articles. These sources were Science Direct from Elsevier Science, SciFinder Scholar from CAS, Science and Technology Collection from EBSCO, and ComIndex from CIOS

Research Paper – First Progress Report
It is very important to monitor the progress from time to time to avoid any surprises. Students were asked to come up with the outline of the paper as a first progress report. The outline would help students to narrow down the vast information they have collected. The outline of paper was finalized for each student. The instructor discussed everybody's progress report and presentation in front of the entire class. The feedback to individual student helped others as well. They were asked to write paper in their own words and refrain from cut-copy-paste. They were urged to mention each and every reference, which is part of professional ethics. They were advised to use ample visual information (pictures, figures, tables, and charts) in the PowerPoint presentation. It was expected that each student would talk about 10 minutes. Students were advised to prepare at least 15 slides.

Research Paper – Second Progress Report
As a second progress report students were asked to bring one page abstract, introduction, conclusions in bulleted form, and references. It is observed that students were more inclined to write in detail about manufacturing processes but were applying fewer efforts in fundamental understanding and elaborating on specific applications. It was very obvious as manufacturing engineering students do not have strong background in areas such as fluid mechanics, mechanical vibrations, dynamics, and strength of material. Some of the students were advised to present their information in the form of 2-3 case studies. Students were also asked to bring title, introduction, and conclusion slides in PowerPoint. They were advised to spend more time on technical content rather than special effects in PowerPoint. Students were encouraged to take any measures that they seem fit to strength their research paper.

Research Paper – Final Report and Final Presentation
Students were asked to bring final report and final PowerPoint presentation. It was expected that report would have 12-15 pages excluding title page and PowerPoint presentation would have about 15 slides excluding title slide. The instructor mainly provided feedback on PowerPoint presentation. The feedback was regarding uniformity in title slides, important missing information, unlinked slides, wrong color selection, little font size, and information in bulleted form. The lecture room with projector was made available to students for mock presentations.

Research Paper – Examination
Two external evaluators with wide industry/research experience in Polymer Chemistry were invited. One of the motives of the research paper was to generate interest amongst undergraduate students in performing research. Therefore it makes much more sense to invite active researchers as evaluators. Their feedback would help in improving this activity. External evaluators realized the way the manufacturing engineer understands polymeric materials. The hardcopy of final

report and PowerPoint presentation was given to these evaluators one week before the exam. Each student was expected to deliver 10-minute presentation that was followed by 2-3 minute question/answer session. The thirty percent weight was assigned to research paper activity. The students were graded by instructor and external evaluators on the basis as displayed in Table 5. The average score for written report was 85% whereas; average score for presentation was 66%. Table 4 displays actual average and standard deviations.

Table 5. Basis for research paper evaluation

Report
1. Creativity
2. Completeness and depth
3. Knowledge of engineering science
4. Use of appropriate engineering terminology
5. Conclusions
Each item 20 points, Total out of 100
Presentation
(a) Presentation Skills
1. Speech volume, projection and pronunciation
2. Quality/clarity/quantity of visual aids
3. Use of time
(b) Questions and Answers
4. Directness and clarity of answers
5. Displays knowledge / competence
Each item 10 points; Total out of 50

Conclusions

In the beginning students had many doubts about the research paper activity. But after lab visit and plant tours they were convinced about the purpose of the research paper. Students developed their research and industry contacts. They took initiatives in revisiting polymer research lab at IEIS, visiting local composite manufacturing plants, visiting library of University of Texas at Austin, and requesting sample material from companies. Many of them used Sci-Finder and other databases. Almost everybody has used 4-5 journal article references in their report. These activities indicate that they have developed research aptitude and independent thinking.

Topics in the course were selected such that they would help students in research paper. More stress was given on fundamental understanding of polymeric materials. Research paper activity increased students' interest in plastics and composites. Three out of ten students have decided to pursue careers in the composite industry. One has started working with author as an undergraduate research assistant from the following semester. Though these numbers are statistically insignificant, they definitely indicate encouraging results.

External evaluators were polymer chemists with wide industry experience. Their feedback was very encouraging. They felt that research paper activity would prepare undergraduate students

for interdisciplinary research. They seemed to be interested in recruiting students on their active research project. This fact attests to the f quality and success of the research paper.

Two approaches were tried to see the students' understanding about manufacturing processes. The first approach was video and lecture followed by plant tour. The second approach was plant tour followed by videos and lecture. It was observed that students' understanding had improved considerably by the second approach. It was also observed that students who have taken this course consider polymeric materials while selecting materials for their capstone project. This is offered every other Spring. Next offering will be in Spring 08. But four students have taken this course as special topics with the author in Fall 07. Two other undergraduate students who received H-SLAMP scholarship are working with author on bio-based composites research. All these results indicate that this course has generated awareness and interest about polymeric materials.

It is felt that hands-on component was missing in this course in the absence of lab component. The author has developed 'Plastics and Composites Lab' with equipments such as injection molding, extrusion, vacuum assisted resin transfer molding, polymer melt indexer, viscometer, and MTS servo hydraulic test. This course covered vast area of plastics and composites therefore; every topic couldn't be taught in depth. The necessity was felt to split this course into two courses 'Plastics' and 'Polymeric Composites'. In the next cycle of teaching besides addition of hands-on component, the appropriate course topics will be selected. Research paper activity will be continued in next cycles of teaching to evaluate this particular teaching approach.

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