AC 2009-1870: INTRODUCING FRESHMEN TO ENGINEERING THROUGH INTERDISCIPLINARY DESIGN AND MANUFACTURING

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Introducing Freshmen to Engineering through Interdisciplinary Design and Manufacturing

Abstract

Kettering University's Introduction to Engineering Course (IME 100) has never been a traditional introduction to Engineering Course. Rather, due to unique history of the University, it once was wholly owned by General Motors, and still maintains an alternating co-op work experience, the introductory was developed to prepare students for their first co-op assignment. This assignment typically involved working in a manufacturing plant. Thus, the course was a combination of lecture supplemented with a hands-on exposure to manufacturing techniques. In 2001 a design component was added to the course.

Recently, a new pilot version of this course was developed as part of the continuous improvement efforts of the IME Department at Kettering. The pilot course differed from the traditional course by incorporating new subject matter and embracing innovative pedagogical teaching techniques. This paper describes the following

1) The systematic development of the pilot course in which "skeptics" played a key role, and
2) The results of this in-house experiment – or the success of the pilot course.

Development of Pilot Course

Continuous Improvement requires that one regularly review how well one is meeting the needs of one's "customers". As IME-100 is required of all engineering freshman, we felt that the engineering faculty best represented our "customers". Our approach to continuous improvement was done in three phases.

<u>Phase 1 - Systematic Survey</u> (note this was automated and a demonstration will be included in the presentation)

We began by systematically surveying faculty from various departments. They participated in a four round survey.

The first round focused on brainstorming, two questions were asked.

Question One focused on topical coverage : "Please List Up to 20 Topics You Feel Should Be Covered in an Introduction to Engineering Course Based on Manufacturing and Design. Each topic should correspond to approximately 25-30 minutes of lecture / class time.

Question Two focused on pedagogy and teaching styles: "Please List Up to 10 Items (non-topic related) that would help the students be successful in the course. These could include the type of assignments required, the size of the class, computer usage, or anything else you feel is important".

The second round of the survey asked the participants to rank the importance of each topic or item on a 1-9 scale. A mathematical algorithm was used to categorize the results, so that the controversial topics and items would be ranked lower. As a result each topic or item was placed into one of five categories: Essential to Include in Course (5), Should be Included in Course (4), Neutral - It Could Be Included if there is Room (3), Should not Be Included in Course (2), and Absolutely Should not Be Included - Waste of Time / Resources (1)

The third round of the survey asked the participants to reviewed the category each topic or item was placed in and rated their agreement, as Strongly Agree, Agree, Disagree or Strongly Disagree. The participants could also comment and propose a new category for the topic or item.

During the fourth and final round participants reviewed those topics or items where there was substantial disagreement or controversy; and revoted they felt appropriate.

Because each participant brought their own experience to the survey process, it is not possible to base the results of the survey on any literature review. However, because of this systematic approach we felt that the most highly rated topics and items represented a consensus view of the participants.

Phase 2 - Review of Results and Creation of Continuous Improvement Report

After the survey was completed an internally peer-reviewed continuous improvement report was prepared. The purpose of the report was to analyze the results of the survey and make a recommendation to the department for further action. The review criteria were:

1) Is the interpretation of the survey valid? If so, how? If not, why not?
2) Are the suggestions practical and based on the findings of the survey? If so, how? If not, why not?

The drafters of the report then responded to the reviewers comments and presented a final report to the department. This report called for a pilot course proposal

Phase 3 - Development of Pilot Course Proposal

Using the approved continuous improvement report as a guide a pilot course was proposed, internally peer-reviewed, revised, and approved by the dept for a two-term trial. A brief summary of the pilot course is below.

The topics recommended for inclusion in the pilot course were:
- Machining and Metal Removal
- Joining of Materials
- Mechanical and Bulk Deformation

- Casting
- Polymer Processing
- Powder Metallurgy / Sintered Materials
- Mechanical Properties of Materials
- Electronics Assembly - Electronics, Packaging, Circuit Board Assembly, IC and Component Fabrication (new)
- Basic Material Classes (new)
- Basic Cost Analysis (new)
- Design Methodology (new)
- Work Design (new)
- Metrology (new in that differences between samples)

The "items", pedagogical techniques or innovations to be included in the pilot course were:

- Integration of Lecture, Lab and Design Lab. This meant that the subject matter presented in class will precede that in the practical lab, the homework and tests will reflect not only subject matter covered in class but in the practical lab, the final examination will cover all aspects of the course.
- Consistent Laboratory Experience
- Higher Level Learning
- Course / Curriculum Integration
- Active Learning

All of the above could be considered new.

Prior to approving the pilot course, recognizing that this was an internal experiment, the following key questions to be answered as a result of this internal experiment were identified and are listed below.

1) Can the "new" subject matter be effectively learned by freshmen?
2) Can the subject matter related to manufacturing processes be effectively learned with a reduced exposure to materials science concepts?
3) Are the students better prepared for the practical laboratory experience?
4) Can the students effectively combine what was learned in lab and class?
5) Does active learning improve student learning?
6) Can students learn the subject matter at higher levels (Bloom's Taxonomy)?
7) Is the integrated approach (including the faculty teamwork) effective and practical?

Results and Analysis

<u>Topic Evaluation</u>

The department has established a standard for rating class performance on a given learning item (test question etc) related to a given topic based on the percentage of students who are proficient or competent.

Proficiency is considered equivalent to an A; the student must

- Demonstrate comprehension of all relevant concepts.
- Demonstrate the ability to correctly apply these concepts to a variety of situations.
- If there are any errors they are few and minor.

Competency is considered equivalent to a C: the student

- Demonstrates knowledge of all concepts but a lack of complete comprehension is apparent.
- Requires some guidance to properly apply concepts in new situations.
- Makes some errors.

The ranking for each learning item based on the fraction of students who are proficient and competent is shown in Table I

Table I: IME Department Rating Table for Individual Learning Items

	Prof.														
Comp	0%	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%
100%	3.15	3.21	3.27	3.33	3.39	3.45	3.51	3.58	3.64	3.70	3.76	3.82	3.88	3.94	4.00
95%	3.13	3.19	3.25	3.31	3.38	3.44	3.50	3.56	3.63	3.69	3.75	3.81	3.88	3.94	4.00
90%	3.10	3.16	3.23	3.29	3.36	3.42	3.49	3.55	3.61	3.68	3.74	3.81	3.87	3.94	4.00
85%	3.08	3.14	3.21	3.27	3.34	3.41	3.47	3.54	3.60	3.67	3.74	3.80	3.87	3.93	4.00
80%	3.05	3.12	3.19	3.25	3.32	3.39	3.46	3.53	3.59	3.66	3.73	3.80	3.86	3.93	4.00
75%	3.03	3.09	3.16	3.23	3.30	3.37	3.44	3.51	3.58	3.65	3.72	3.79	3.86	3.93	4.00
70%	3.00	3.07	3.14	3.21	3.29	3.36	3.43	3.50	3.57	3.64	3.71	3.79	3.86	3.93	4.00
65%	2.75	2.77	2.79	2.81	2.83	2.85	2.88	2.90	2.92	2.94	2.96	2.98	3.00	3.50	
60%	2.50	2.54	2.58	2.63	2.67	2.71	2.75	2.79	2.83	2.88	2.92	2.96	3.00		
55%	2.25	2.31	2.38	2.44	2.50	2.56	2.63	2.69	2.75	2.81	2.88	2.94			
50%	2.00	2.08	2.17	2.25	2.33	2.42	2.50	2.58	2.67	2.75	2.83				
45%	1.75	1.77	1.78	1.80	1.82	1.83	1.85	1.87	1.88	1.90					
40%	1.50	1.53	1.57	1.60	1.63	1.67	1.70	1.73	1.77						
35%	1.25	1.30	1.35	1.40	1.45	1.50	1.55	1.60							
30%	1.00	1.07	1.13	1.20	1.27	1.34	1.40								
25%	0.83	0.84	0.85	0.86	0.87	0.88									
20%	0.67	0.69	0.70	0.72	0.74										
15%	0.50	0.53	0.56	0.58											
10%	0.33	0.37	0.41												
5%	0.17	0.21													
0%	0.00														

The Performance based on Graded Records for a given topic was determined based on the average rating for all learning items based on that topic.

- If the Average Rating is less than 1.5 then the Performance is Unacceptable
- The Average Rating must be 1.5 or higher for the Performance to be Marginal
- The Average Rating must be 2.0 or higher for the Performance to be Acceptable

- The Average Rating must be 2.7 or higher for the Performance to be Good
- The Average Rating must be 3.5 or higher for the Performance Rating to be Outstanding

The students were also surveyed at the end of the course to determine how well they felt they learned the topic. The possible responses were Unacceptable (0), Marginal (1), Acceptable (2), Good (3), or Outstanding (4). The Performance based on Student Feedback was determined as follows.

- In order for the Rating to be Outstanding the Avg must be 3.5 or higher, at least 75% of the responses must be Good or Better, and no more than 15% of the responses can be Less Than Acceptable.
- In order for the Rating to be Good the Avg must be 2.7 or higher, at least 50% of the responses must be Good or Better, and no more than 25% of the responses can be Less Than Acceptable.
- In order for the Rating to be Acceptable the Avg must be 2.0 or higher and no more than 35% of the responses can be Less Than Acceptable.
- In order for the Rating to be Marginal the Avg must be 1.5 or higher and no more than 50% of the responses can be Less Than Acceptable
- Otherwise the Rating will be Unacceptable

The overall performance for the topic is based on a combination of the student feedback rating and the graded performance rating as shown in Table II.

Table II: Determination of Overall Topic Performance based on Combining Graded Performance and Student Feedback

Performance Based on Graded Records	Performance Based on Student Feedback	Overall Performance	Rationale
Unacceptable	Any	Unacceptable	If Based on the Graded Records the performance is unacceptable, the survey rating is not relevant
Marginal	Unacceptable	Unacceptable	If the rating based on student performance is only marginal, yet student feedback indicates that they did not even learn at this level it is unacceptable
	Marginal - Outstanding	Marginal	If the student performance is marginal, the survey responses cannot show that learning occurred at an acceptable level.
Acceptable	Unacceptable	Marginal	If the student feedback indicates that learning occured at an unacceptable level yet the student performance indicates that

			it is acceptable a rating of marginal is appropriate.
	Marginal-Good	Acceptable	If the student performance is acceptable and the results of the survey are neither outstanding nor unacceptable the rating should be acceptable
	Outstanding	Acceptable/Good	If the student performance is acceptable, yet the student rating is outstanding there is an indication that the level of learning is slightly better than acceptable.
Good	Unacceptable - Marginal	Acceptable/Good	The student feedback indicates that the level of learning is slightly less than good.
	Acceptable-Outstanding	Good	In order to be considered outstanding both the student performance and feedback must be outstanding.
Outstanding	Unacceptable-Good	Good/ Outstanding	
	Outstanding	Outstanding	

The results of student performance in the topical areas is shown in the following below in Table III.

Table III: Overall Performance in Topics

Topic	Winter 2008	Summer 2008
Mechanical Properties of Materials	Acceptable	Acceptable
Metrology and Sample Differentiation	Good	Good
Mechanical Processing	Acceptable	Acceptable
Casting	Good/Outstanding	Acceptable
Powder Processing	Good	Acceptable
Machining and Material Removal	Acceptable	Acceptable
Electronic Manufacturing	Good	Good
Joining of Materials	Good	Acceptable
Polymer Processing	Good/Outstanding	Marginal
Design Methodology	Acceptable	Acceptable
Manufacturing Layout	Acceptable	Good
Cost Analysis	Unacceptable	Marginal

It must be noted that the during the Winter 2008 term the course was taken by second term freshmen and during the Summer 2008 term by first term freshmen. During both terms students rated the effectiveness of the course and the instructor as Good.

Thus with the exception of basic cost analysis it is shown that all topics can be taught at an acceptable level.

Analysis and Results of Key Questions

Key Question 1) Can the "new" subject matter be learned effectively by freshmen? The results are shown in Table IV.

Table IV: Performance in New Topics

New Topic	Winter 2008 Performance	Summer 2008 Performance
Electronic Manufacturing	Good	Good
Design Methods and Methodologies	Acceptable	Acceptable
Manufacturing Planning (Work Design)	Acceptable	Good
Basic Cost Analysis	Unacceptable	Marginal
Metrology (Are Samples Different)	Good	Good

Based on the evidence presented above the answer is **yes**. Incorporating cost analysis is challenging and will be addressed later in this paper.

Key Question 2) Can the subject matter related to manufacturing processes be effectively learned with a reduced exposure to materials science concepts? The results are shown in Table V.

Table V: Performance in Manufacturing Processes

Topic	Winter 2008 Performance	Summer 2008 Performance
Mechanical Processing of Materials	Acceptable	Acceptable
Casting	Good / Outstanding	Acceptable
Powder Processing	Good	Acceptable
Machining and Material	Acceptable	Acceptable

Removal		
Joining of Materials	Good	Acceptable
Polymer Processing	Good / Outstanding	Marginal

Based on the evidence presented above the answer is **yes**. The marginal performance in polymer processing during the Summer 2008 term is due to the sole evaluation being a final examination question where te students were expected to determine which casting process is most similar to a polymer processing process. They did well on this in the Winter and not in the Summer. More than one question needs to evaluate this topic.

Key Question 3) Are students well prepared for the practica experience? The results are shown in Tables VI ,VII, and VIII Below

Table VI: Student Response to Survey Question About Practica Preparedness

	Winter 2008	Summer 2008
Response Rating	Good	Good
Average	2.84	3.31
Responding Good or Better	68.4%	85.7%
Responding Less Than Acceptable	10.5%	2.9%

Table VII: Student Performance on Lab Preparation Quizzes on Preparation Quizzes

Winter 2008

Number of Students Proficient (10/10)	Number of Students Competent (8/10)	Other Students	Item Rating
182	112	37	3.81

Summer 2008

Practica	Number of Students Proficient (10/10)	Number of Students Competent (8/10)	Other Students	Item Rating
Hardness / Metrology	48	0	0	4
Mechanical Testing / Sheets	40	6	2	4

Green Sand Casting	43	0	5	4
Lost Foam Casting	41	3	5	4
Lathes	33	1	0	4
Mills	48	0	0	4
Gas Welding	20	2	2	4
Arc Welding	40	4	2	4

Table VIII :Feedback from Practica Instructor on Student Preparedness Summer 2008 Only

Practica	Rating
Hardness/Metrology	Acceptable/Good
Mechanical Testing / Sheets	Good
Green Sand Casting	Outstanding
Lost Foam Casting	Marginal
Lathes	Marginal
Mills	Marginal
Gas Welding	Marginal
Arc Welding	Acceptable

Based on the evidence presented above the answer is **yes**. In both terms the students rated their preparation as good, although the Summer 2008 Term showed a significant improvement, probably due to the revised practica manual and its required reading for the class sessions. In both terms student performance on the lab quizzes was outstanding. The number of marginal ratings by the instructor may have been due to the standard being overly optimistic:

> The majority of students needed more than a brief introduction (15-20 minutes) from the instructor, in order to do what was needed to complete the exercise.

Key Question 4) Can the students effectively combine what was taught in the class sessions and practica? The results are shown in Table IX below.

Table IX: Student Response to Survey Question About Ability to Combine Subject Matter

	Winter 2008	Summer 2008
Response Rating	Good	Good
Average	2.71	2.78
Responding Good or Better	65.8%	69.4%
Responding Less Than Acceptable	7.9%	11.1%

Based on the evidence presented above combined with the student performance on HW, tests and the final examination the answer is **yes**. Each homework assignment had questions related to the practica. Several test questions on each test and the final examination required the student to combine the subject matter. The topical performance shows that they were able to combine the knowledge effectively.

Key Question 5) Does active learning improve student learning? The results are shown in Table X below.

Table X: Student Response to Survey Question About Active Learning Effectiveness

	Winter 2008	Summer 2008
Response Rating	Acceptable	Acceptable
Average	2.14	2.60
Responding Good or Better	42.9%	65.7%
Responding Less Than Acceptable	31.4%	14.3%

Based on the evidence presented above combined with the student performance especially on the HW but also on the tests and the final examination the answer is **yes**. The survey used is in the documentation binder(s). The survey response for acceptable was:

> Participating in the class sessions enabled me to complete at least half the HW=s in 4-6 hours, through the experience answering concept questions, team problems and discussion questions. *I am not sure if I will better retain knowledge of the subject matter compared to what would have occurred in a more traditional format.*

The survey response for good was:

> Participating in the class sessions enabled me to complete the HWs in 4-6 hours, through the experience answering concept questions, team problems and

discussion questions. *I feel that I might better retain knowledge of the subject matter compared to what would have occurred in a more traditional format.*

The Winter Term Survey did not include the times, which may have accounted for the discrepancy.

Key Question 6) Can the students learn the subject matter at the higher levels of Bloom's Taxonomy? The results are shown in Table XI below.

Table XI: Student Response to Survey Question About Higher Level Learning

	Winter 2008	Summer 2008
Response Rating	Acceptable	Good
Average	2.30	2.74
Responding Good or Better	43.2%	71.4%
Responding Less Than Acceptable	16.2%	14.3%

Based on the evidence presented above combined with the student performance on the HW but also on the tests and the final examination the answer is **yes**. All test questions required students to perform at the analysis level of Bloom=s Taxonomy or higher.

The survey response for good was:

> I was usually able to correctly, although not always confidently answer questions and solve problems which require correctly either tying together different concepts or apply what I learned in new contexts. I am pretty sure that this experience will allow me to retain their knowledge of the subject matter better than if the class were taught in a more traditional format.

Key Question 7) Is the integrated approach practical and effective? The results are shown in Tables XII and XIII below.

Table XII: Student Response to Survey Question About Integration of Class Sessions, Practica and Design Studio

	Winter 2008	Summer 2008
Response Rating	Acceptable	Good
Average	2.34	2.97
Responding Good or Better	50.0%	72.2%
Responding Less Than Acceptable	15.8%	8.3%

The survey response corresponding to a rating of good was:

> The class-sessions and manufacturing practica usually (but not always) flowed together well. The instructors knew what each other was doing and tried to use this knowledge to enhance student learning. The design studio was only barely integrated into the class-sessions by the end of the term.

Table XIII: Student Ratings of the Interaction Between Class Sessions, Practica, and Design Studio

Effectiveness of Interaction Between	Winter 2008	Summer 2008
Class Sessions and Practica	Good	Good
Class Sessions and Design Studio	Marginal	Marginal
Practica and Design Studio	Marginal	Marginal

Based on the evidence presented above combined with the student performance on the HW but also on the tests and the final examination the answer is **somewhat**. It is clear that the interaction between the class-sessions and practica are good. However there needs to be more interaction between the design studio and the other parts of the course. The demodularizaton was only half successful.

Assessment, Conclusions, and Recommendations

Successes

The Pilot Course was successful in several respects

- It demonstrated that new topics, identified as important, can be introduced into the Introductory Engineering Course based on Design and Manufacturing. These are: electronics manufacturing, design methods and methodologies, manufacturing planning (work design), and "are samples different".

- It was demonstrated that this course can be considered exemplary from a pedagogical perspective. Active and higher level learning were successfully applied in accordance with University's Mission and Vision, as well as that of the Department of Academic Affairs. One significant measure of this was that there was no lecture in the Pilot Course.

- Significant progress was made in demodularizing the course. The needless boundary between the class-sessions and practica has been broken down. A slight reorganization of the order of practica experiences and a new tensile test practica were successful and can be expanded. The adaptation of the practica manual is also a testament to this.

Remaining Challenges

The incorporation of basic cost analysis into the course is possible but will require a little more work. In the Winter term cost was covered during the last class session and it was assumed that students would make the connection on the final. During the summer students were challenged to think about cost and it was somewhat successful. Also the discussion of time value of money was limited. Because this was the last class session there was no homework assigned on this topic. If reading and sample problems which are relevant to the course are prepared, it may be possible to include this topic in the course and ensure it is learned at an acceptable level.

It is clear that the design studio needs to be better integrated into the course. Dialog needs to be initiated to ensure that this happens.

Subject matter covered after the second test needs to be evaluated more vigorously. A third test, possibly in conjunction with the design studio should be considered.

Lessons Learned

It is clear that the pedagogical innovations were effective, however in order for them to be effective students need to be guided through the learning process. The on-line materials (homework tips, test preparation sheets) are key. Many of the students brought a lap-top to class and used it to better perform on the team problems.

Recommendations

To build on the success of the Pilot Course the following should be considered to make a fully successful course.

- New practica and design studio experiences should be considered. A culminating practical experience in the work design lab, where the students assemble something from the parts they made in the various other practica would be a great culmination. These could include sheet metal shell for a circuit, a decorative column made on the lathe, a decorative base made in the machining lab on to which they can mount the green sand casting. Discussions along this line should commence.

- A text is vital to this course. During the summer I modified the "lab manual" so that it met the needs of the Pilot. I made it required reading for the class sessions. Several students commented that it was better than the text. As a faculty we can all contribute to the preparation of a course text based on the practica manual. Most of us can contribute. IE faculty could contribute to the "are samples different", cost-analysis, work design sections. We could continue to break down the barrier between the design studio and ask them to write sections.

- The first two practica experiences used in the pilot should be adopted. By testing the hardness of various heat treated metals the students can determine if a part is in spec. By comparing the thicknesses of the spindles one can determine if the samples were made to the same spec. The second practica included each student conducting a tensile test on a heat treated tensile bar. The class pooled the data and determined how different the results were. While more work is needed on this using statistics to relate hardness to strength could introduce the students to some IE concepts.

- The electronic resources need to be continually improved so that the pedagogical innovations can be continued. We can do more on-line.

- More education is needed as to why the systematic development is necessary and the importance of each of the steps.

Final Comments

This paper demonstrates not only the effectiveness of a newly developed course, but
- how an internal educational experiment can be conducted to determine the successfulness of a pilot course, without comparison to other courses
- how changes can be made to a large foundational course through systematic consensus building.

Both are equally important in the opinion of the authors.