Paving the Road to Immediate Impact at the Workplace in Engineering

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Abstract *– "It is my fir st day on the job after graduating from a prestigious engineering institute. All my hard work has finally paid off. I've learned everything there was to know in school. I took every class and sat through every lecture. I'm ready for the real world." T his is the thought that most graduates have when they leave school only to find out that the reality is much different. What about the things that you cannot learn in a classroom? Graduates need to learn how to communicate with other people, how other di sciplines perform tasks, how to deal with different personalities to complete a task, and numerous other items that are not taught in the classroom. Keeping this in mind, are graduates ready to start from day one? What does industry expect out of recent engineering graduates? Industry wants engineers that are ready to start from day one. A panel of industry partners pointed out 6 qualities that they expect a recent graduate to have. Today's engineer must be able to work closely with different discipline s while maintaining his technical expertise. They must have leadership skills. Being able to act as a change agent between departments is essential. Engineers must have the ability to provide adequate conflict resolution skills. System integration skill s are also important to the industry partners that were poled. Kettering has designed an Integrated Systems Capstone course to meet the 6 primary needs of industry. In this course, students from different disciplines (Mechanical Engineering, Manufacturin g Engineering, Industrial Engineering, Electrical Engineering, and Computer Engineering) will team up to mass -produce a product of their choosing. They will perform all steps from concept to product realization. As in industry the students will focus mos t of their energy on the tasks that correspond to their specific disciplines with a number of crossover tasks. In order to get the project done within the term a plan needs to be developed and communication between disciplines is of the utmost importance. There are numerous benefits to an institution developing this program beyond just satisfying industry's needs. For the university, benefits include a better relationship with industry, higher enrollment, and a strengthened bond between departments, just to name a few. In this Integrated Systems Capstone course little time is spent in the classroom lectures. The students concentrate on to learning things that the classroom does not teach while staying within the structure of their degree program. They not only synthesize what they have learned but also gain: teamwork experience, collaborative finesse, an ability to comprehend the global picture of engineering, the urgency to be innovative, and drive to become effective leaders.*

Index Terms *– Systems I ntegration, Automation, Inter -Disciplinary, Capstone course*

INTRODUCTION

US companies are growing leaner and leaner [1-3]. Fewer engineers are hired for the same jobs, and they are expected to know more, do more, be more efficient, more effective, and broader in their knowledge and skills [4,5]. Dauch, Chairman and CEO of American Axle & Manufacturing of Detroit [6] said that cross-functional teams of manufacturing, design, procurement and Quality assurance teams are essential around the globe He also said that collaborative engineering/manufacturing or simultaneous engineering must drive production and process development. The challenge is to provide the collaborative atmosphere. Engineering curricula have concentrated on dealing, in-depth, with specific subjects.

As a result, graduates are not prepared to survive in this new world of engineering. There are a few universities that have held interdisciplinary courses. Examples are at University of New York at Binghamton [7] where academic projects are teamed with industry to cover project management, ethics and impact of technology on environment, Rochester Institute of Technology [8] and Valparaiso University [9]. Most of them are 2 course sequences and concentrates mainly on the technological aspects of engineering, not the combined forces of engineering, manufacturing, and management. Dym used project based learning to enhance knowledge. He covers project management and tea dynamics besides engineering design [10]. What qualities are expected of these engineers of the future?

GOAL

Our goal is to have industry identify qualities that are not visible in the recent graduates they hire and derive solution(s) to prepare the students.

OBJECTIVES

To complete this goal certain objectives need to occur in a very specific order.

1. Extract information from industrial advisors and define current deficiencies
2. Develop a strategy to encapsulate them into a course
3. Course description
4. Implementation
5. Assessment

Here at Kettering University we are in the business of educating graduates that are ready to make an impact in industry from day one. For 85 years Kettering, with the help of industry, has been giving students real work experience while providing a top-shelf education. Once again Kettering has asked industry for assistance. An advisory committee was formed for this NSF supported project (grant no. 0234478). It consisted of a company president, a vice president of operations, one retired VP, three Directors, a general manager, and a manger, all in engineering or information technology. "What can Kettering do to graduate students that are more job-ready, particularly in manufacturing?"

The leaders of industry that were there turned out a variety of well-received, but surprising answers. In their frustrations, the advisors began to develop 6 qualities, which they do not see in current engineering graduates. With these qualities strategically placed into a capstone course, Kettering can help pave the way for immediate impact in the workplace. The following is the list of the qualities that recent graduates should have:

- **Leadership Skills**: Industry needs students that are ready to lead right out of college. Industry trains its potential leaders through a combination of third-party training agencies, and internal training. There is a decrease in the number of graduating seniors that have the skills necessary to take a leadership role when hired.
- **Conflict Resolution**: Students need to have a way to resolve conflicts in industry. People do not always agree, it is a fact of life. How a person deals with a disagreement, or conflict, is the true mark of a leader.
- **Ability to act as a Change Agent**: A change agent is an individual that mediates any necessary changes. The changes include system integration, new equipment integration, and circumstances where more than one department have to combine their energy. A common scenario depicts two departments getting together and arguing over responsibilities. More time is spent arguing than working and the task takes longer than necessary to accomplish. A change agent will mediate between the individuals, or departments, to decrease the time spent resolving a difference.
- **Out-of-the-Box Thinking/Innovation**: Industry needs creativity. More importantly the United States needs people that can come up with new concepts and ideas to keep jobs at home.
- **Inter – Departmental Collaboration Skills**: This idea is very similar to a change agent. In the absence of a change agent employees need to be able to work with other parts of the business world, both internal and external to the company. This could even mean working with individuals in other countries. Employees have to recognize and respect differences in cultures and philosophies.
- **Knowledge and Experience in System Integration**: Students that graduate have a problem when it comes time to integrate systems. When integrating a system there are numerous aspects involved: manufacturing, electronics, programming, ergonomics, floor or line workers, this list could go on and on. With all the different aspects, experience is needed. That experience will come from Kettering's formal education and co-op experience.

THE PLAN

Kettering has set a series of goals to help provide industry with the students it wants without a complete change in the current curriculum. Since students are Kettering's products and industry is the consumer, Kettering needs to change to supply industry with its needs. Kettering will have completely job ready graduates that, if promoted properly, can increase student enrollment. The set of criteria is as follows:

- **No drastic changes in the current curriculum**: It is very important to incorporate solutions to industry's problems into the current curriculum. Kettering just underwent a curriculum reform in 2002. An additional reform will not be feasible. Therefore, changes must fit into the current curriculum.
- **Use current classes to address industries problems**: One main goal is to use a current class that combines solutions to all the problems. The class will need to be an integration-based class that will clearly and concisely address all the concerns of industry.

Along with the criteria there are also some key steps, towards completing the objectives that cannot be ignored.

- **Allow as many students as possible to enter the class**: This is necessary because more than half of industry's concerns deal with integration. A class that integrates different disciplines is desired. Generally, at Kettering, after a student's first year there are no technical classes except for occasional electives, in which students from different departments can take together.
- **Promote class to increase enrollment in the class**: If the benefits of the class are not shown to the students then they will not take it. This will be an excellent class to put on a resume and the students need to know why.
- **Out-of-the-Box thinking/Innovation will be added to the class structure**: There will be a patent simulation that will be added to the final project to promote creative/innovative thinking. Once an idea is used then it will be off limits. This will force Out-of-the-Box thinking.

DETAILED DESCRIPTION OF IMPLEMENTATION

Based on the above criteria, there are two areas of applications: (a) incorporate criteria to existing classes (b) create a new class to adopt all the criteria.

Patent Idea

This idea will be implemented into the current framework of the undergraduate Computer Integrated Manufacturing (CIM) class. In the class there is usually a final project that pits teams of students against each other. For example, when a student group comes up with an idea for a gripper design, fixturing design, or an assembly process the group submits a write up to file a mini-patent. When one group files the mini-patent the other groups cannot use the concepts that were patented. This will spur out-of-the-box thinking.

Senior (Integrated Systems Capstone Course)

Currently Kettering has a senior capstone course that all seniors have to take. This class is a culmination of the student's entire program. Our goal is to use this class as a base for a new capstone class that will incorporate solutions to the six problems that industry addressed. In this Class:

- Students will gain an integrated interdisciplinary experience through the practice of concurrent engineering and teamwork by working efficiently within the simultaneous demands of design, analysis, manufacturing, quality, cost, and timing.

The new class will be a combination of Mechanical Engineering, Industrial Manufacturing Engineering & Business, and the Electrical & Computer Engineering departments. The premise of the class will be to create a product from concept to product realization using the resources of the CIM lab. In the Kettering University CIM lab there are 4 Fanuc LR Mate 200iB's, 1 Fanuc M-16iB, a Haas VF-2 CNC mill, a Haas SL-10 CNC lathe, 13 graphics focused computers with Intel Pentium 4 – 2.4 GHZ and a CDRW, a Litton Automated Guided Vehicle (AGV), a Denford Triac CNC mill, and a Denford Mirac CNC lathe. Each Engineering discipline will require certain prerequisite skill besides overall workplace safety.

The primary responsibilities are delegated to the students in different disciplines. Throughout the term, they will not work in a vacuum. They will coordinate with other student groups to achieve their tasks more efficiently.

- **Manufacturing Engineer**: employ automation among CNC equipment, robotic equipment, an AGV, and an ASRS; select material and develop appropriate steps for the processes that lead to efficient cycle times.
- **Mechanical Engineer**: design and analyze product and tooling, produce prototypes, material selection, and tolerance determination.
- **Industrial Engineer**: Integrate Scheduling, Inventory, and Process Control, Statistical Analysis, workplace design, ergonomics.
- **Computer Science / Engineering**: write programs to monitor and control machines that can give real-time feedback and tracks efficiencies.
- **Electrical Engineer**: design and construct circuitry and electronics applications for all Input/Output (I/O) hookups, sensors, and safety devices and necessary external electromechanical tooling.

Table 1 shows an outline of tasks that will need to occur each week for the class to be a success CNC programming, robotic programming, or system integration are desired, though not required. The class will begin with the students selecting a project from a pool of projects previously determined by the faculty that are preferably supplied by industry partners. It will be up to the students to decide what the part will look like, how it will be manufactured, and what aspects of the process can be monitored. Interaction among the different engineering disciplines is the key to success. The mechanical engineers need to work with manufacturing to design a product and associated tooling that can be machined. The CS/CE team will need to work with the IE's to determine which aspects of the process should be designed and programmed to monitor and compare within a given time frame. These are just a couple of examples of group interaction as one can see there are many more scenarios that require teamwork. During the class there will be seminars that address the issues of Leadership/Conflict Resolution and Out-of-the-Box thinking/Innovation, methods for being an effective change agent, and teamwork skills.

Change Agent

Each team of disciplines will have a change agent. The change agent is the key person to interface between the cross-functional teams. There will be a change agent for each team and an overall project change agent. The change agents could be management students. If everybody from both teams interacted together then communication would be difficult. The idea of a change agent is to represent the team, keep the team pointed toward the overall task at hand, and provide any additional resources to the team. *A change agent is not a group leader* . With just one person from each team conversing then changes and compromises will occur much easier.

The concept for this class was developed shortly after the NSF conference at Kettering University in December of 2003. This class is projected to start in 2005. The delay is there because the teachers from the different departments will need to converse over the details of the class and a workload model needs to be ironed out with administration.

In order for the class to be a success there will need to be resources committed from all over the school. Each department will need to commit one faculty member to oversee each discipline. There needs to be a push from the departments to market the class through the student's scheduling advisors. Help from Kettering's Business Program will also be needed when the class is running. The Business/Marketing students will be able to market the fact that Kettering has this unique class and help increase enrollment. Other resources that will need to be committed are:

- A small budget
- The equipment in the CIM lab (which is well equipped except for a few upgrades and retrofits)
- Raw material for final project, for any prototype builds, tooling, and fixturing
- Significant devotion of time from all professors that oversee each discipline
- The faculty and a selection committee, comprised of industry personnel, will provide a list of projects
- A management faculty member, or a speaker, for the seminars in weeks one and two, and to conduct the interviews in week six with the change agents and group leaders.

Week	ME	IE/MFG/MGMT	CE/CS
1	Project introduction, select Change Agents and group leaders, establish goals and objectives, and a Leadership/Conflict Resolution seminar (by MGMT professor)		
2	Out-of-the-Box/Innovation seminar, develop Gantt charts for each group, change agents meet and combine each groups Gantt charts.		
3	Product design	Develop familiarity with the CIM equipment	

4	Tooling design, make prototype product	Make prototype product, manufacturing schematic, develop plan for monitoring, order raw material	Develop plan for monitoring, more equipment familiarity
5	Tooling and fixturing machined	Assist in machining the tooling and fixturing and the monitoring flow chart.	Develop flow chart for monitoring
6	Mid-Term presentation, catch up time, teacher one-on-one with group leaders and change agents.		
7	Program the equipment	Assist in the programming of the equipment, and the start of the monitoring program.	Start monitoring program
8	Continue from Week 7		
9	Continue from Week 8 and start testing		
10	Testing		
11	Finalize testing and final presentation		

TABLE 1
OUTLINE OF ALL 11 WEEKS FOR THE NEW SYSTEM INTEGRATION CAPSTONE COURSE

BENEFITS

There will be so many benefits when the project is completed and the class is actually running. The projected benefits of implementing the System Integration Capstone class include: little or no cost, productivity Improvement, higher Enrollment, higher Employer satisfaction ratings, higher percentage of graduating seniors with jobs, strengthen the bonds between Kettering's departments, solutions to each of the six problems presented to Kettering at the NSF conference, creates interest in manufacturing classes.

- **Cost**: A huge benefit to implementing the class is that it will have minimal capital investment and course expenditures. All major equipment is in place with few upgrades needed. The largest investment will be the time of the instructors (at least one from each department) that will be involved in teaching the course and raw material requirements.
- **Productivity Improvement**: The productivity of the CIM lab will increase because for each term the System Integration Capstone course is taught there will be one more part/product that the CIM lab can reproduce on a moments notice.
- **Higher Enrollment**: If marketed properly, the fact that Kettering can change to meet the needs of industry can supply a boost to enrollment.
- **Higher Employer Satisfaction ratings**: Employers will be happy with the quality of students that are graduating from Kettering. Kettering will have met the needs of employers. This will lead to Kettering receiving higher ratings when reviewed by employers.
- **Higher percentage of graduating seniors with jobs**: With students having more experience in system integration the already high percentage of graduating seniors with jobs will increase.
- **Strengthen bond between departments at Kettering**: At Kettering there usually is not much interaction amongst the faculty from the different teaching departments. With the class using students from the different departments the faculty will have to work together to create an effective and efficient class. This will strengthen the university as a whole.
- **Leadership skills**: This problem from industry will be addressed through the seminar during week one of the capstone class. It will also be addressed through out the term by having students act as change agents and group leaders. Perhaps the role of the change agent or group leader could rotate through out the term.
- **Conflict Resolution**: The solution to the conflict resolution problem will be a seminar during the first week of the class. During the class there will be more than one situation that will arise amongst the groups that will need some sort of conflict resolution. The best way to learn to swim is to be thrown in the pool.
- **Ability to act as a Change Agent**: This is a benefit because this industry wide problem will be addressed by employing the use of change agents into the project.
- **Out-of-the-Box thinking/Innovation**: This benefit comes from a seminar during the second week of the System Integration Capstone class and from the new patent addition to the current CIM class final project.

- **Inter-departmental collaborations**: Not only is this a benefit for the faculty, as discussed earlier, this is a benefit for the students while working at their co-op jobs with individuals that possess different skills. The ability to work with people from different departments is critical in industry and Kettering will fill that need.
- **Knowledge and experience in system integration**: The name of the class is System Integration Capstone. This fills a need in industry for students to have experience setting up and maintaining system integration projects, thus it is a benefit.
- **This class will create interest in manufacturing classes**: With an influx of mechanical engineers actually taking jobs as manufacturing engineers a minor in manufacturing could be a popular choice in the coming years. This class will help to create an interest in manufacturing and would help more mechanical engineers stay an extra term to get a minor in manufacturing.

In order for this project to be a success there will need to be a well-developed plan to implement the project. At Kettering University the CIM lab is equipped for this capstone course. Below is a cookbook for the implementation of the System Integration Capstone course:

1. **Create a working Demonstration**: This step is to prove that the CIM lab equipment can be used for the base of this project. The equipment needs to have the ability to be integrated and this ability needs to be displayed before planning on the class can begin. This demonstration is currently in the design stage. It will be the construction of a set of chess pieces. There has been a trial run in Dr. King's IME 408 Automation class in which 4 students from different disciplines (EE, ME, MFGG, and an international student) successfully completed a project. They integrated the CIM labs Fanuc robot with the Haas mill and Haas lathe to create a rook chess piece. They completed the assignment by having a live demo of their rook being created and also supplied a written report.
2. **Get Department Heads to buy in**: The basis for implementation of any CIM application is to get the buy in from the top down and implement from the bottom up. This could not be truer than in this instance. In order for the class to be a success the department heads of all the departments involved need to have a complete buy in. This buy in will help the faculty members to be more involved.
3. **Select the faculty to be involved**: This point is very critical. The faculty that are going to over see the student groups need to be able to work together. Many compromises will need to occur throughout the process of clearly defining and creating the class. The faculty will need to always keep in mind the overall goal of the project.
4. **Select the pre-requisites courses**: This is important because it might be necessary for students to have working knowledge of the CIM lab equipment. This determination is up to the faculties that are running the class.
5. **Determining the list of projects for the students**: This step will involve the faculties meeting with some leaders of industry. This probably will occur during a one-day conference that devises a list of projects that are challenging but not too challenging given the students' time frame and potential skill levels.
6. **Develop a detailed class plan**: Earlier there was a base plan for the class. Once the faculty members are assigned they will want to modify or add to the plan depending on their preference.
7. **Make sure that class plan conforms to ABET and graduation requirements**: This is probably the most important step. If the class does not conform to ABET then it cannot be taught or counted towards graduation.
8. **Determine a grading scale**: The professors need to develop a grading scale for the class. The grading scales will be specific to each student's discipline.
9. **Create an evaluation survey**: It is important that the faculties have their own evaluation survey to give the students after they take the class. This will allow the class to mold and change to make it more effective over time.

CONCLUSION

The vision of any educational institute is that their students will have learned everything they need to know, while attending the school. Ideas like communication and inter personal skills are not easily taught in the classroom. Every employer wants graduates that can make an immediate impact. This System Integration Capstone course will help to provide students with the skills to work with people as if they were co-workers.

The idea of a class called System Integration Capstone is a very cost effective idea. The only costs are the minimal costs for the raw materials involved and the faculty's time. The benefits that will directly impact the university are higher enrollment in the future and more students staying longer to get a manufacturing minor (in the Kettering system). The rest of the benefits directly affect the satisfaction levels of Kettering University. Employer and student satisfaction levels will strengthen Kettering's, already distinguished, reputation. The satisfaction levels increase will not be seen initially, it will be a gradual increase. Adding a System Integration Capstone course with inter-disciplinary aspect is a win-win-win situation for industry, students, and universities.

ACKNOWLEDGEMENT

This and related research and development are founded by National Science Foundation Grant No. 0234478. The authors wish to thank the following industry partners: Blaise Klenow, Director of Chrysler Vehicle Manufacturing Information Technology Management, DaimlerChrysler Corporation; Richard Johnson, General Manager of Material Handling Systems, FANUC Robotics North America, Inc.; Roderick Johnson, V.P. of Operations, Fernco, Inc.; William Russo, Director of Manufacturing Engineering, Ford Motor Company; T.J. Zeller, Manager of Manufacturing Engineering, Ford Motor Company; Gwan Lai, Director R&D, Vision-Ease Lens, Inc.; Robert Skodzinski, President, Gerotech, Inc.; Patrick Lynch, Sales Engineer, Gerotech, Inc.

The authors would also like to thank Kettering Academic Administration for their support of the class projects conducted as a prototype for the proposed Capstone course.

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