THE DEVELOPMENT OF MANUFACTURING CASE STUDIES

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Abstract - In manufacturing engineering education, there is a need for problem-solving projects that reflect real issues to supplement or replace drill and practice problems. Authentic activities offer an opportunity to apply new knowledge and skills to manufacturing engineering problems, test theories, and draw conclusions in a safe environment with the help of peers and mentors. Case studies add relevance and real world context to manufacturing engineering education. At Greenfield Coalition, two case studies were developed on the basis of real issues faced by the Focus:HOPE Center for Advanced Technologies (CAT), a tier-one supplier to the automotive industry. The first involves superficial irregularity - determining why some, but not all, batches of aluminum manifold castings discolor during machining. The second study involves dimensional irregularities - stabilizing bore dimensions for a pulley used in the manufacture of diesel engines. Both studies require student teams to brainstorm potential causes, generate solutions and select the best method for elimination of the problems. The final deliverable for each case is a report similar to one that might be presented to management of a given organization. By employing case studies in manufacturing engineering education, students learn to apply skills and techniques to new situations just as they would have to perform on the job.

Index Terms – case study, manufacturing, problem solving, reality-based learning.

A NEED FOR PROBLEM-SOLVING AND HIGHER LEVEL THINKING

In manufacturing engineering education, there is a need for problem-solving projects that reflect real issues to supplement or replace drill and practice problems. Traditionally, problems arise when students are asked to apply the theory they have learned from a book or in the classroom to a relevant, real-world example. Students, familiar with a lecture-style class and comfortable with examination questions directly related to the information presented in class, are much less comfortable in situations requiring the application of the theory they have learned, to new and unexplored examples. Furthermore, traditional lecture-style classes do not effectively promote retention and transfer to other contexts. The result is that students are not exposed to, nor required to use higher levels of thinking for many years while attending college, yet engineering problems almost always require higher levels of thinking.

Industry recognizes and acknowledges these deficiencies in their recent graduate employees. Automotive manufacturers often hire graduates only to immediately place them into training programs, up to two years in length, to help them develop the skills necessary to work in teams and solve engineering problems that exist in a manufacturing environment. Considering competition and lean manufacturing practices, it is necessary for students to develop these teamworking and problem-solving skills prior to entering the workforce.

EDUCATIONAL RESPONSE

Engineering educators seem to effectively satisfy the first three levels of Bloom’s taxonomy. However, the last three levels: analysis, synthesis, and evaluation, are the crux of what engineers, technologists, and technicians do; yet evidence suggests it is the weakest portion of engineering educational programming. Students need authentic activities which offer an opportunity to apply new knowledge and skills to manufacturing engineering problems, test theories, and draw conclusions in a safe environment with the help of their peers and mentors. Some schools of engineering collaborate with local industry to provide just these types of reality-based examples as a context for learning. Others have extensive cooperative education programs that give the student exposure to manufacturing problems in a technical, rather than textbook setting.

The reality-based approach adopted by the Greenfield Coalition (GC) addresses the last three levels of Bloom’s taxonomy. By taking the philosophy and pedagogy of problem-based learning but utilizing a real situation from manufacturing rather than a textbook problem void of variables present in the natural, contextual environment, students must gather all the data from numerous sources, organize it in a meaningful way, and determine possible solutions given the constraints ever present in the real world. This is exemplified in the manufacturing case studies described below.

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CASE STUDIES

Case studies are ideal for illustrating complex concepts, especially common in engineering. Horton (2000) suggests the use of case studies as an excellent way for learners to practice judgment skills necessary in real life situations that are not as simple as textbook problems. As instructional strategies are concerned, engaging critical thinking skills through case studies is among a recommended set of activities (Bonk & Reynolds, 1998). Case studies add relevance and real world context to manufacturing engineering education. Because case problems are typically ill-defined and can have several different and potentially correct outcomes, students have the opportunity to explore many paths and share perspectives with peers. With the guidance of peers and mentors, teams of students will make decisions based on their problem-solving investigation to determine if and when they need to abandon their current path of exploration in favor of another or if they should pursue and support their current resolution strategy. Guy (2000) states that “the rich case allows students to gain safe experience in practicing fundamental skills needed in their careers: they need to plan and set up interviews and focus groups, question clients by email or other means, design questionnaires, analyze the information obtained, formulate ideas and write reports…giving students practice in taking on professional roles in a protected environment.” This precisely captures the intent and full capability of the GC cases.

At GC, two case studies are being developed, based on the real issues faced by the engineers at the Focus: HOPE Center for Advanced Technologies (CAT), a tier-one supplier to the automotive industry. Both studies require the student teams to define the issue, brainstorm potential causes, generate solutions and select the best method for elimination of the problem.

The candidates (GC students) at the Focus: HOPE Center for Advanced Technologies (CAT) have a unique learning environment. They have an advantage over students enrolled in traditional manufacturing engineering curricula because they have the daily opportunity to apply new concepts learned in the classroom to real situations on the manufacturing shop floor. This characteristic of the curricula at the GC is not only unique, but also provides a natural contextual environment for the application and transfer of new knowledge and skills. In terms of teaching and learning, a better environment could not be simulated, therefore, it became a critical component of the teaching and learning strategies at GC. In order to share this advantage and paradigm with other students enrolled in similar engineering programs so that they might learn from the experiences of the CAT candidates, GC had to somehow export these experiences. Presenting case studies from the CAT in an online environment seemed the obvious choice.

CASE #1: THE STAINING OF AN ALUMINUM CASTING

The CAT at Focus: HOPE is a QS9000 certified tier one supplier to the automotive companies in Detroit, Michigan. One regular customer, a supplier of engines that has a good reputation and strong sense of aesthetics, purchases throttle body intake manifolds for V-6 engines. The manifolds arrive at Focus: HOPE in the form of raw aluminum castings. The castings are inspected and then sent to the shop floor where they are machined on CNC machining centers. After the casting is machined, the “as cast” surfaces turn a dull gray color. The machined surfaces maintain a bright luster, in sharp contrast to the dull cast surfaces. Although the machined manifolds function as they should, the poor appearance is unacceptable to the customer.

The candidates have the ability to explore a set of resources online in order to investigate this case. Interviews with critical members of the manufacturing team (such as the Chief Engineer and Machine Operator) responsible for manifold production are available for review (Figure 1).

![Interview with Key Personnel](image)

**FIGURE 1**

**INTERVIEW WITH KEY PERSONNEL**

Financial reports that detail scrap and rework costs are provided as well as a complete price breakdown for the part. A process map details each process the part undergoes while at the CAT. Photographs of raw parts, machined parts that show discoloration, and parts that have been saved through reworking and acid washing are given (Figure 2). In summary, all resources available to an onsite engineer are provided online for candidates to utilize during their case examination. It should be noted that candidates have access to more information than is needed to resolve this problem. However, it is their responsibility to decipher the information from various sources and eliminate the superfluous information. They must propose alternatives to resolve the problem while being careful not to reach a dead end. In terms of Bloom’s taxonomy, their assignment is to...
analyze, synthesize and evaluate the problem. They are to write their findings and recommendations in a manner that is clear, concise, and follows a standard writing format. Report guidelines specific for this case are online. These guidelines help the student prepare a comprehensive report, including writing the problem statement, documenting all considerations in solving the problem, evaluating possible solutions and substantiating one resolution over other. WWW links are available for students to explore similar situations, material properties, manufacturing processes and much more, as they deem necessary. Finally, mentor notes are available for additional assistance to the candidates. These include a series of tasks and issues related to the case and its objectives, serve as a tour guide and give necessary learner support when they need and want it.

**CASE #2: IRREGULAR DIMENSIONAL TOLERANCES ON A PULLEY**

This case involves a multi-sheaved pulley used in high-powered engines. Some of these pulleys have dimensional tolerance irregularities. All of the rough turning operations are performed on a Cincinnati Milacron CNC turning center. Finishing operations, except the counter bores, are completed in the same machine during the same machining cycle, to ensure concentricity.

This is not a new job to Focus: HOPE as it been manufactured for a significant number of years, but always in small batches. Although an order is placed each month, the batch sizes vary from five to 25 pulleys. It is important to realize that while this job is not a large one, it is consistent and reliable. It is referred to as a “bread and butter” job and hence, the problem must be controlled, if not eliminated.

Similar to other case studies at GC, the candidate has access to a wealth of resources related to this case. Interviews with key personnel have been recorded and are accessible online. Media (video and animation) depicting the boring operation on this pulley are included (Figure 3 & 4). In addition, the process sheet, product flow diagram, holding fixture information, operator tasks and other information related to this part and the processes it undergoes at the CAT are provided.

The candidates are informed from the beginning stages, that the problem is associated with the two counter bores. Their assignment, as with the previous study, is to analyze, synthesize and evaluate the problem or problems. It is their responsibility to identify the problem, find its source or sources, report findings, and make recommendations.
The roles of the student and the faculty member are changing. It is critically important to be aware that the use of the web-enabled case studies does not occur without the leadership of an instructor. The instructor at GC plays several roles simultaneously: traditional instructor of course concepts, mentor and coach during the case investigation, and finally that of a supervisor challenging the recommendations from a manufacturing enterprise perspective (Schuch-Miller & Plonka, 2001)\(^6\). Moreover, follow-up classroom discussions, an integral component of the case design, allow learners to reflect, summarize and solidify their own learning and structure it in a way that is meaningful to them (Hidi & Anderson, 1986)\(^7\).

Case study documentation and support materials online allow students to obtain background information on the situation, research components involved in the case and define the problem for themselves. They can collect a history of the situation through virtual interviews. They can research the processes and machinery involved in the operations through exploration of process sheets, CAD drawings, and scrap reports. Further, WWW links are provided to prompt online research for solutions. The candidates are provided enough information to initiate a plan and formulate potential solutions. Then, students are expected to justify their rationale for each step taken toward a solution. The final deliverables can be in the form of written and oral reports, similar to what would be expected of them on the job.

**CLASSROOM DYNAMICS**

As a result of the discovery and collaborative learning approach, students’ and instructors’ responsibilities and expectations were markedly different than more traditional approaches to teaching and learning. During the pilot offering of these case studies, the students seemed to expect the solutions to be revealed to them rather than having to conduct their own investigations and postulate solutions. When the instructor was confronted with the significant upheaval over the increased expectations, it was critical that guidance and instructor support be presented without resulting in conducting the investigation for them.

After completion of the first case study, the teams interacted with one another. They found that they all discovered two sources of trouble that were identified by every team. The sources that did not match were defended to the fullest by the various teams that proposed them, and with good justifications. Students in previous classes did not have the enthusiasm that was evident at the end of the 2003 class. The 2003 group had narratives that were much more precise and justifications were much more compelling than their counterparts in earlier years.

**FEEDBACK**

Student feedback following the pilot indicated a greater sense of accomplishment and achievement by being directed to demonstrate the ability to troubleshoot problems, generate solution alternatives and justify one decision over others. As part of a formative evaluation process, one student commented on a survey that “good problem solving skills were developed.” Another student added that “it was nice to work on real world problems.”

Incorporating case studies in manufacturing processes classes is not novel. Most textbooks include case studies. Unfortunately, they do not foster interaction, and typically have only one correct answer. While this is both useful and interesting, there is little room for student exploration and hence, higher order learning. Using these case studies developed by GC, the students had greater options for problem resolution, investigation and thought processing.

**STUDENT ACHIEVEMENT**

The test site for these GC case studies was Lawrence Technological University in a class entitled TIE2153, Manufacturing Processes 2.

The same grading scale and categories have been used since 1998. Historically, the case studies account for 33 percent of the overall grade. The final grades for the Spring 2003 group were all at or above 3.00, and the average was 3.47. The average overall grade in the 2002 class was 3.01. Considering the consistent instructor and rubric for this course, one variable, the use of the GC case studies, seems a probable cause for the improved achievement of learners.

**CONCLUSION**

By employing case studies in manufacturing engineering education, students learn to apply skills and techniques to new situations, just as they would have to perform on the
job. Collaborating with other students closely resembles the team approach to taskforces and project teams that have been gathered to resolve issues in a manufacturing facility. The use of technology for delivery of the case study and supporting materials promotes the sharing of these case studies to educational institutions, both in academia and industry, outside of Focus: HOPE and Greenfield Coalition.

**DISSEMINATION**

These case studies can be integrated into several courses, including Manufacturing Processes, Engineering Economics and Material Removal. For more information about Greenfield Coalition, their reality based approach to teaching and learning, or the two manufacturing case studies, including viable solutions to each case, access the following website: [www.greenfield-coalition.org](http://www.greenfield-coalition.org).

In addition to the case studies mentioned in this paper, GC offers a full suite of case studies designed and developed with the same pedagogical approach, in the following subject matters: Engineering Economics, Facilities Design, Metal Forming, Operations Management and Statistics. These case studies are available for public use and access to them can be obtained by submitting a request to greenfield_support@focushope.edu. Keep in mind that any portion of the case studies, the whole or any component, can be utilized.

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**REFERENCES**


