Strategies for the Development of Web-based Engineering Case Studies

Authors:

Don Falkenburg, Wayne State University, Greenfield Coalition, Detroit, MI 48202, falken@focushope.edu
Diane Schuch-Miller, Wayne State University, Greenfield Coalition, Detroit, MI 48202, schmild@focushope.edu

Abstract — *The paper describes a methodology that the Greenfield Coalition has developed to design and implement a series of case studies. The methodology is founded on knowledge about adult learning, principles of instructional design, and research on alternatives to traditional lecture-style instruction that allow learners to see the value and meaningfulness to their coursework. In brief, case studies provide a contextual situation in which learners can practice problem-solving and solution-justification processes without significant risk while receiving coaching from their instructor.*

Index Terms — *case study, manufacturing, problem solving, reality-based learning*

A NEED FOR HIGHER ORDER THINKING

The student view of most engineering curricula is one which focuses on individual topics or courses. *'If I take enough classes, I get a degree, right…?'* As faculty, we seldom integrate knowledge among courses. Yes, we do expect prerequisite skills to have been developed, but how much of our time is spent building integrated skills in a curriculum. When we fail to do this, students are not able to understand how their individual study units are integrated into a whole [1]. Many employers expect students to have proven skills in the areas of teamwork, written communication, self-management and problem solving [1], yet these skills are rarely elicited, let alone tested, in educational settings.

Traditionally in engineering education, students have difficulty when asked to apply the theories presented in textbooks or discussed in class to a real world problem. Learner expectations are consistent with a lecture format class with tests that directly reflect the content presented. As a result, students are uncomfortable exploring situations and problems that are different from examples. Unfortunately, this traditional approach to teaching and learning in engineering does not effectively encourage knowledge and skills 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 [2].

In a recent issue of the ASEE Prism, Bill Wulf, president of the National Academy of Engineering, is quoted [3]:

> " *There is a clear disconnect between the practice of engineering and what is being taught.* He came to this realization when he returned to the academic world after running his own business. *It hit me like a two-by-four between the eyes,* he says. Wulf believes that part of that disconnect is due to the faculty's lack of real world experience… Wulf makes it clear that he does not intend to criticize faculty members. What he seeks is a system *that enriches the faculty with a complementary set of experiences and talents, and thereby enriches that education of our students."*

The linked issues of compartmentalized learning and our inability to bridge the educational experience to real world engineering problems are major problems with current engineering curricula.

THE VALUE OF CASE STUDIES

Case studies have revolutionized teaching within both the business and medical communities. The case methodology is a framework to embed learning in an environment that is as close to the real world as possible. It challenges learners to explore resources, make assumptions, and construct solutions. Case studies are also ideal for illustrating complex concepts, especially common in engineering. Horton [4] 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 [5].

Case studies can also be used to introduce students to the complex interactions among technology, business, and ethics. The Laboratory for Innovative Technology in Engineering Education (LITEE) at Auburn University has produced a number of case studies. One of these describes a turbine-generator unit in a power plant vibrating heavily and shaking the building.

Two engineers recommend conflicting solutions. The plant manager, must to make a decision that could cost the company millions of dollars [6].

GC CASE STUDY APPROACH AND RATIONALE

Most often, case studies are presented in a narrative format, describing the initial events triggering the exploration or study, the identification of and diagnosis of the problem(s), and the strategies and treatments for resolution. While this methodology introduces the real world element into the learning context, the learner plays a passive role. Further, it does not promote the development of problem solving skills, the application of processes, and learner collaboration.

The Greenfield Coalition (GC) at Focus:HOPE, a coalition of five universities, seven manufacturing companies, the Society of Manufacturing Engineers, and Focus:HOPE (a civil rights organization dedicated to intelligent and practical action to overcome racism, poverty and injustice in Detroit and its suburbs), has developed an approach in the construction of a set of case studies to support our academic programs that requires a more active role from the students. Funded under the Engineering Education Coalitions Program at NSF, Greenfield has established a new paradigm in manufacturing engineering education leading to degrees in both Manufacturing Engineering and Manufacturing Engineering Technology.

The candidates (Greenfield Coalition (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 Greenfield Coalition 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.

Although most engineering programs cap the degree program with a senior design experience, targeting a real world problem, we believe that the development of a rich set of case studies framed for the engineer and distributed throughout the curriculum will greatly enhance the ability of our students to develop the real skills required by engineers to solve the problems they face in the workplace

GC CASE STUDY DESIGN METHODOLOGY

GC examined Bloom's taxonomy [7] for categorizing levels of abstraction – knowledge, comprehension, application, analysis, synthesis, and evaluation – and recognized that it is the last four that tend to be weak in engineering education. As a result, the methodology for constructing case studies assures that learners have the opportunity to reach these higher levels necessary in the engineering field.

The instructional design of all cases follows Gagne's Nine External Events [8] beginning with getting learners attention by presenting the case situation or scenario. This description of the case includes general information but does not identify the problem to be resolved. Rather, this description provides just enough information to engage the learner to investigate the problem themselves or in small groups. From this point, it becomes the responsibility of the learner to uncover what they believe to be the real problem. In order to do so outside of the CAT environment, GC has captured and represented online a wealth of resources related to each case to examine and contemplate. These resources are organized by typical activities that would be performed, to prevent the learner from feeling overwhelmed at any given time during the case analysis. While each case has a different set of resources, many media formats are used throughout all of the GC cases. Following the exploration of resources, the learner is expected to compile a report, typically consisting of identification of the problem, options for resolution of the problem, the selection of one option, and the justification for that selection over other alternatives. In conclusion, there is a case debriefing discussion, where students can discuss differences of supported resolution options and lessons learned from their investigations.

The home page for the case serves as the learner guide. From this page, students are able to view the recommended set of investigation activities, expectations for assessment of their investigation as well as the full list of resources provided for their perusal. Basic navigation, similar to GC courses, is accessible at any time, from the left-hand side and across the top of the interface, providing constant availability of broad level information. Further, the web interface is organized to keep learners from becoming frustrated or lost. Figure 1 shows that once a case is selected, the specific scenario is depicted, and instructions and activities are outlined.

If, at any time, the learner feels overwhelmed by the rich set of information provided and feels that the exploration through the resources seems unproductive or inefficient, they may consult the mentor notes. Mentor notes, 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. The learner is not required to follow the tasks and/or consider the issues in a lock-step fashion. Rather, Mentor Notes help to orient the learner to the items necessary for consideration in a thorough investigation of the situation. Filipczak [9] refers to this as scaffolding or "guided discovery", by retaining learners opportunity to explore while still making certain that the established objectives are attainable. Candidates may choose to execute all, some, or none of the suggested tasks. Additionally, this compilation of expert notes can be applied to many situations. As a result, it functions as a tool for learning as well as a job aid for real manufacturing engineering situations.

Often case studies at GC serve as a capstone for the courses, however, they are not tests. Therefore, learners may refer to the mentor notes as often as necessary without negative consequence. The most important purpose is that students can apply previously learned concepts and principles, and practice decision-making and problem-solving processes in a non-threatening but very real situation.

Scaffolding is also provided for the course instructor in an area entitled Faculty Interface, in the event that the instructor using the case study materials is not as knowledgeable about a particular topic as the case study designer and/or developer. These notes, similar to the mentor notes, were recorded during the pilot offering of the case study to assist subsequent instructors adjusting to their new roles as a facilitator of learning and a manufacturing plant supervisor posing a variety of questions and concerns common in a real engineering setting.

EXAMPLES

We illustrate our approach by describing two web-enabled cases. Each of these is framed by a real manufacturing engineering problem and is set in the production facility of the Center for Advanced Technologies at Focus:HOPE in Detroit, Michigan.

CASE I: ENGINEERING ECONOMICS

The Situation: Management at a tier-one supplier of engine pulleys has identified an inability to meet shipping schedules. They believe this is a result of poor product flow through the balancing machine operation. The supplier would like to expand its customer base for this family of products, but they are concerned that if they cannot keep up with shipping requirements for current business, they will not be able to handle new business requirements. On the average, 700 parts are produced daily. Although not all parts need to be balanced, about 200 parts are balanced daily. The average scrap rate for the pulleys is approximately 25% It is management's belief that the current machines are outdated and inefficient, and that downtime during the balancing process is great enough to consider replacing the machines. It is evident that management is fairly certain the balancing process is the root of the problem. With the operations being so interconnected, the actual source of the problems may lie in another area of the process. They are willing to research and consider other possible trouble areas, however.
Resources: Learners are provided a set of links to information, which will help them define the problem and explore the solution:

- Process flow for balancing operation,
- Process map,
- Scrap versus production data,
- Balancing operation financial data,
- Price breakdown for pulleys,
- Bracket scrap summary report,
- Photos of machines and surrounding area,
- Balancing process production log,
- Machine scrap lost dollars report,
- Current situation described by interviews with key personnel:
  - Director of Manufacturing
  - Plant Manager
  - Associate Candidate
  - Manufacturing Supervisor
  - Application Engineer
  - Financial Analyst
- Sample process sheet
- Industry links

In this case, a process map and product path are depicted using still images with mouse-over animation for additional information. Further, MSWord and Excel documents such as part price data, scrap rates and subsequent lost dollar reports are viewable in the web browser. Students can even simulate a conversation with important personnel by reviewing the interview section of the resources. Here, streaming video clips and transcripts of real interviews conducted by CAT candidates can be viewed. WWW links to vendors of balancing machines and/or information about new balancing technology make it possible for learners to research new technology or uncover how other companies resolved similar situations

Objectives and Assessment: The objective for this Case includes a requirement that the learner demonstrate an ability to define a problem from the situation described and to make recommendations to management which take into account: the effect of interest, taxes, project life span and uncertainty on decision making. Assessment of learner performance is evaluated through a team report. The guidelines for this report are listed here:

Identify the Problem: Use available resources to assess the situation and identify the problem. Write a problem statement, which briefly outlines the issues and their effects. It should also give an overview of management's concerns.

Considerations: Document considerations in solving the problem. Based upon the considerations, formulate a list of possible solutions. List the advantages and the areas of concern with each alternative.

Financial Analysis: Analyze the benefits and costs of each solution (including the Do-Nothing Alternative), and evaluate the revenue potential for each alternative. Provide documentation utilized in the analysis, such as, cash flow diagrams.

Recommendations: Based upon your research and analysis, recommend a course of action to resolve the situation that you identified as the problem. Support your recommendation with the findings of your analysis.

Supporting Documentation: Provide the documentation of any analysis you conducted in order to reach your conclusions. Examples include: Cash flow Diagrams, Decision Trees, and Sensitivity Analysis.

CASE II: IRREGULAR DIMENSION TOLERANCE ON A PULLEY

The Situation: Management of a tier-one supplier to the automotive industry has identified dimensional irregularities in the series 3887 turned pulleys that are made for their customer, Fenders Racing. Concern has been raised for several reasons but principally, this class of pulleys is physically the largest manufactured within the production facility. This is a double-bore pulley, typically run in small batches. Rather than collecting SPC data, the bores are measured on every part. This measurement takes place at the second workstation (secondary boring). The part has tight tolerances (.0009"), plus GD&T runout specifications of .001". With these conditions, heat becomes a factor and the co-efficient of thermal expansion must be considered. Many parts produced have undersized bores when the part returns to standard temperature (68°F or 20°C). These can be re-machined, but not usually with good results.

This is a job of varying size. The source of this job is an important customer, Fenders Racing. It is important to realize that our goal is to eliminate rejections, and it is imperative that no scrap parts are shipped to the customer. The best method of assuring that scrap parts are not shipped to the customer is to produce only good parts.

Resources: A number of resources are provided regarding the instability of the bore dimensions in turned pulleys at Focus:HOPE's Center for Advanced Technologies. These include part drawings which can be viewed with a CAD drawing plug-in, still pictures of the processing stages, and a video and an animation of the critical boring operation. Other information include process sheets, a description of cutting fluids, tool forces, scrap production data, and interviews with key personnel. A starter list of industry links is also provided.

- Part drawing
- 3D view of pulley
- Part specifications
- Product flow of pulleys – from arrival through shipping
- Pulley at various process stages:
  - Rough boring
  - Finishing bore
  - Drilling
  - Balancing
- Operator tasks
- Boring operation video
- Boring operation animation
- Holding fixture information
- Cutting fluids used in boring process
- General tool forces and deflection information
- Scrap versus production data
- Bracket scrap summary report
- Price breakdown for pulleys
- Machine scrap lost dollars report
- Process sheet
- Current situation described by interviews with key personnel:
  - Chief Engineer

- Manufacturing Engineer
  - Tooling Coordinator
  - Cell Leader
  - Machine Operator
- Relevant manufacturing links

Objectives and Assessment: The objective for this Case includes a requirement that the learner demonstrate an ability to define a problem from the situation described and to make recommendations to management which investigates the impact of cutting tools, holding fixtures, cutting fluids, loads and abnormal deflection, operator impact, and the quality of the castings. In addition teams must determine and evaluate the potential resolution options and recommend implementation strategy The team-based report is used to evaluate the performance of students.

Identify the Problem: Use available resources to assess the situation and identify the problem. Write a problem statement, which briefly outlines the issues and their effects. It should also give an overview of management's concerns.

Considerations: Document considerations in solving the problem. Consider all of the following: Cutting tools, Holding fixtures, Cutting fluids, Excessive loads, Abnormal deflection, Operator-controlled influences, Quality of castings, Other issues identified by your own instincts and/or research

Evaluate possible solutions: Formulate and analyze the possible solutions. Identify implementation strategies as well as shortcomings of each solution.

Recommendations: Based upon your research and analysis, recommend a course of action to resolve the situation that you identified as the problem. Support your recommendation with supporting documentation.

Supporting Documentation: Provide the documentation of any analysis you conducted in order to reach your conclusions. Examples include: research, cost analysis, and difficulty with implementation due to equipment, policy, etc.

FEEDBACK FROM STUDENTS AND INSTRUCTORS

Although students were informed of the case-based approach, they were quite surprised at the depth of the investigation needed to support one alternative over others. Students questioned the instructor to reveal the problem rather than determine it (or them) for themselves. Once the instructor challenged them to figure it out, they were more motivated to explore the resources provided. Some student comments indicate that it takes longer to gather the critical information than had been previously thought. This is a good lesson to learn since it closely models real world situations where critical information is not always known, collected or readily available.

At times, students were required to revise their report in order to make it more useful to a potential supervisor. Though this created significant upheaval from the students, significant changes were ultimately made to the final report submitted for assessment. Knowing the expectation of a shop floor manager helped to produce a thorough and good quality report.

Student perspectives regarding this case-based approach changed throughout the course of the case investigation. In the beginning, it was perceived as difficult and challenging only. At the conclusion of the experience, students felt greater confidence in their ability to apply their knowledge and skills to real situations. Further, the experience of working on a real case, where the variables are plentiful and where they may be more than one possible resolution, gave them valuable experience and set their expectations for working in the field. The students genuinely appreciated the depth of knowledge gleened from working with a mentor and coach: their instructor.

When the instructor was confronted with the significant upheaval over the increased expectations, it was critical that guidance and support be presented without resulting in conducting the investigation for them. This was a challenge since typically, when students ask for assistance, the instructor will help them find the answers. With these cases, there is a fine line between guiding their investigation and asking questions of the students to further their investigation, and helping them with the answers to all their questions.

Also, the likelihood that students will ask questions that the instructor does not know the answer to is greater with these case studies than with course content. As a result, the instructor must be comfortable with this potential situation, and return responsibility for finding the answer back to the students. Without a doubt, this marks a shift from the 'sage on the stage' approach to teaching.

IMPLICATIONS FOR ENGINEERING EDUCATION

No doubt, the roles of the student and the faculty member change when using this methodology. Although the use of the web-enabled case studies was not designed to 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 [10]. In these roles, the student gets the opportunity to apply problem solving skills, analyze and synthesize collected data and conduct their own evaluation of options. Clearly, this allows learners to achieve the higher levels of Bloom's taxonomy.

Moreover, the debriefing classroom discussions give learners an opportunity to assess their own skills, techniques, compare with and learn from others, and set goals for their future. Sharing lessons learned makes possible the improvement of processes for subsequent investigations. This 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 [11].

Guy [12] 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.

DISSEMINATION

GC offers a full suite of case studies designed and developed with the same pedagogical approach discussed, in the following subject matters: Engineering Economics, Facilities Design, Manufacturing Processes, 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.

In addition, more information about the Greenfield Coalition and their reality based approach to teaching and learning is available through the following website: www.greenfield-coalition.org.

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FIGURES AND TABLES

FIGURE 1
EVERY GREENFIELD CASE IS DESCRIBED BY A SITUATION

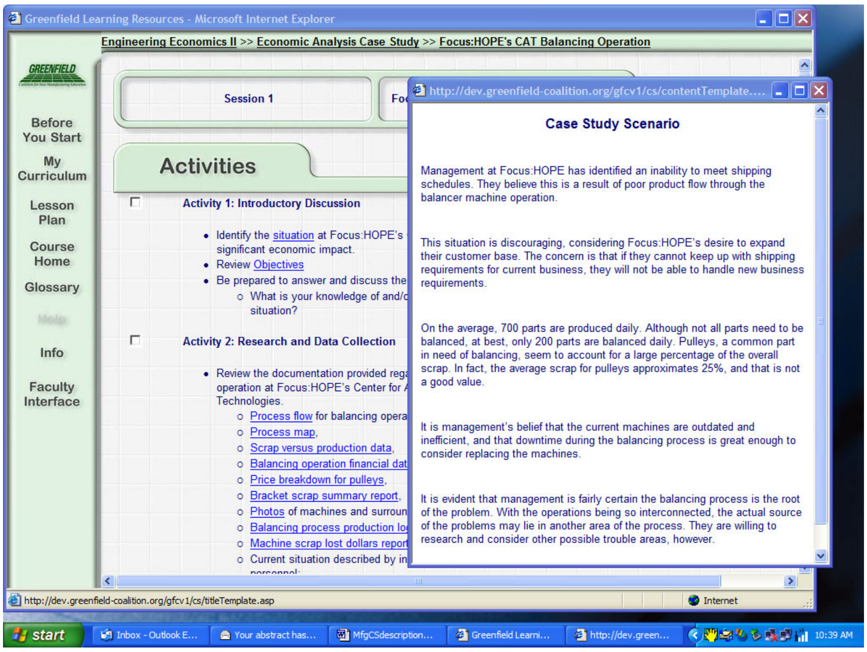


FIGURE 2
THE PULLEY FOR DIMENSIONAL IRREGULARITY CASE

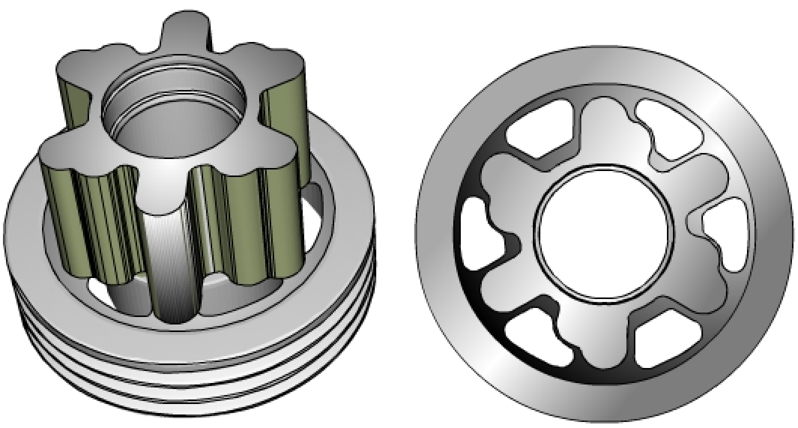
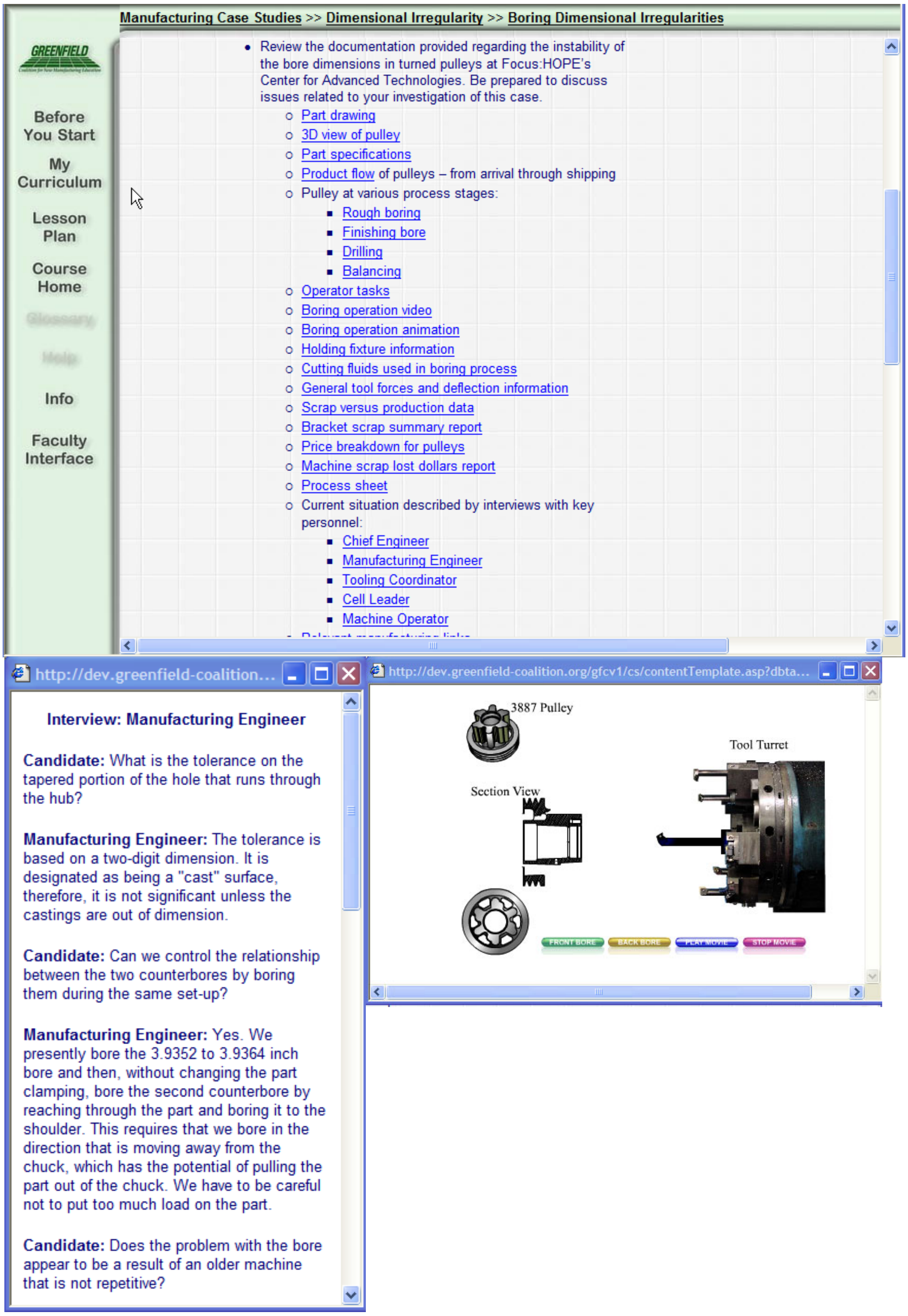


FIGURE 3
RESOURCES: DIMENSIONAL IRREGULARITY CASE


Manufacturing Case Studies >> Dimensional Irregularity >> Boring Dimensional Irregularities
GREENFIELD
Before You Start
My Curriculum
Lesson Plan
Course Home
Glossary
Help
Info
Faculty Interface
Review the documentation provided regarding the instability of the bore dimensions in turned pulleys at Focus:HOPE's Center for Advanced Technologies. Be prepared to discuss issues related to your investigation of this case.
Part drawing
3D view of pulley
Part specifications
Product flow of pulleys – from arrival through shipping
Pulley at various process stages:
Rough boring
Finishing bore
Drilling
Balancing
Operator tasks
Boring operation video
Boring operation animation
Holding fixture information
Cutting fluids used in boring process
General tool forces and deflection information
Scrap versus production data
Bracket scrap summary report
Price breakdown for pulleys
Machine scrap lost dollars report
Process sheet
Current situation described by interviews with key personnel:
Chief Engineer
Manufacturing Engineer
Tooling Coordinator
Cell Leader
Machine Operator
http://dev.greenfield-coalition...
Interview: Manufacturing Engineer
Candidate: What is the tolerance on the tapered portion of the hole that runs through the hub?
Manufacturing Engineer: The tolerance is based on a two-digit dimension. It is designated as being a "cast" surface, therefore, it is not significant unless the castings are out of dimension.
Candidate: Can we control the relationship between the two counterbores by boring them during the same set-up?
Manufacturing Engineer: Yes. We presently bore the 3.9352 to 3.9364 inch bore and then, without changing the part clamping, bore the second counterbore by reaching through the part and boring it to the shoulder. This requires that we bore in the direction that is moving away from the chuck, which has the potential of pulling the part out of the chuck. We have to be careful not to put too much load on the part.
Candidate: Does the problem with the bore appear to be a result of an older machine that is not repetitive?
http://dev.greenfield-coalition.org/gfcv1/cs/contentTemplate.asp?dbta...
3887 Pulley
Tool Turret
Section View