Engineering Education Coalitions: The Greenfield Retrospective

Donald R. Falkenburg[1]

Abstract*—The Greenfield Coalition at Focus:HOPE is 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). 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. This paper takes a retrospective look at the Greenfield Coalition. It begins with the original design of the coalition program, discusses issues that have challenged achieving that vision, and describes Greenfield's refocus on its intent build an educational experience rich in real-world manufacturing examples. The paper describes the accomplishments of the coalition, and describes a sampling of Greenfield learning products.*

Index Terms ¾ Focus:HOPE Greenfield Coalition, manufacturing, NSF Education Coalitions,

HOW IT BEGAN

The Greenfield Coalition at Focus:HOPE is a coalition of five universities, three university affiliates, six manufacturing companies, the Society of Manufacturing Engineers, and Focus:HOPE [1]. The impetus for the Greenfield project was the sense that most academic studies in manufacturing engineering were devoid of real manufacturing experiences. The idea for the coalition was born in Focus:HOPE, a human and civil rights organization located in Detroit, Michigan.

> *Coalition Members:* Lawrence Technological University, Lehigh University, Michigan State University, University of Detroit Mercy, Wayne State University; *Affiliate Partners:* Ohio State University, University of Michigan, Walsh College.
> *Industry Partners:* Cincinnati Machine, DaimlerChrysler, Detroit Diesel, Electronic Data Systems, Ford Motor Company, and General Motors

Focus:HOPE supports an amazing web of programs to underpin its educational objectives. Founded in 1968 after the urban riots in Detroit, it *pledges intelligent and practical action to overcome racism, poverty and injustice*— to make a difference within the city and its suburbs. Focus:HOPE began by feeding the undernourished needy (women with children and then adding senior citizens) but quickly added programs to enable inner city youth to acquire knowledge to seize opportunities for highly skilled and well paying jobs.

Today, an individual may begin the journey by enrolling in *First Step* or *FastTrack*. These four and seven week programs use computer-based learning to build fundamental skills in mathematics and English. When the student graduates from *FastTrack*, they have skills certified at the ninth and tenth grade level in reading and math. This provides the appropriate prerequisite skills for entering the *Machinist Training Institute (MTI)*. MTI is a thirty-one week program in which students earn certification in the operation of material processing equipment (machining), metrology, computer-aided design, computer numerical control, and the associated math, computer, and communication skills.

Greenfield presents an opportunity for graduates of MTI to cap their practical experience with further studies toward

advanced university degrees. Those students who qualify, enter a 24 week pre engineering program after completing MTI's basic machining program. After a series of diagnostic tests and interviews they become *Candidates* in the Center for Advanced Technologies (CAT)—Focus:HOPE's manufacturing facility. The Center for Advanced Technologies (CAT) is a not-for-profit entity, which is a first tier supplier of manufactured components and systems to Ford, General Motors, DaimlerChrysler, Detroit Diesel, and the U.S. Department of Defense. The Candidates are employed by Focus:HOPE and work in a

[1] Donald R. Falkenburg, Director Greenfield Coalition, College of Engineering, Wayne State University, Detroit, MI 48202 falken@focushope.edu

broad range of manufacturing, production, and support activities. While this employment provides financial support, more importantly it becomes a real-world laboratory to support learning.

The partners of the Greenfield Coalition saw Focus:HOPE as an opportunity to support a new approach to manufacturing education—one in which real-world manufacturing applications drive learning, rather than the more traditional academic approach of *theory looking for an application*. A key tenet of the Greenfield proposal to NSF targeted the integration of production experiences with the work activities of the Candidates at the Focus:HOPE Center for Advanced Technologies. The framers of the Greenfield proposal imagined an educational experience in which the Candidates would work and study in the same facility. They would experience the functional operations involved in production, and they would be exposed to flexible manufacturing system architectures, manufacturing systems design, as well as process and quality control. Candidates would rotate through positions in production and manufacturing engineering, and learn through their experiences. At the same time, the candidate would be guided by a combination of mentors/teachers, including CAT functional supervisors, vendor trainers, faculty from coalition universities, and industry experts. Learning in the Greenfield Coalition would be modular and underpin skills and understanding to support a progression of work experiences. Thus, the work environment and the learning experience would be mutually supportive, and build a new breed of engineer who not only had theoretical understanding of manufacturing, but also practical hands-on experience.

CHANGE AND RETARGETING THE FOCUS

While the ideas that motivated this strategy were sound, accomplishing the intent was difficult. Focus:HOPE has two linked organizations. One that oversees the educational programs of the candidates, and the other that manages it production business. The Greenfield strategy described in the preceding section would require unprecedented cooperation between competing functions. In an ideal world, it would be possible to coordinate the work assignment of candidates to link to their plan of study. In the real world, however, economic pressures on the production facility made this seamless coordination difficult, if not impossible. Adding to the difficulty is the fact that academe and industry are two distinct cultures that organize and value knowledge differently. University faculty most frequently organize learning with a topic-specific focus, while production engineers and managers typically integrate across many disciplines and frame learning using a situation-specific point-of-view. Both cultures recognize the value and relevancy of the other but have no tools, or system level procedures to facilitate the translation. Typically, the recognition of credit for learning outside the academic classroom is negotiated with a professor, chair, or dean on a case-by-case basis.

Compounding the problem, the Greenfield Coalition had difficulty in articulating its strategy for transitioning its experience at the Focus:HOPE Center for Advanced Technologies to its campus-based programs and beyond the coalition. Although there were successes in implementing experiential education, it was difficult for Greenfield to build a sustainable strategy that met the expectations of the National Science Foundation to make substantive change in the conduct of engineering education.

In the 1993 proposal to NSF, *'Electronic Pull-Down Learning'* was proposed by Greenfield to support the experiential education process. Building on a modular delivery system in which learning was packaged into small one-credit packages, Greenfield intended to use multi-media tools to allow candidates to access the knowledge they needed to support their assigned job. Again, the idea of both job flexibility and flexible educational delivery supporting each other was a noble idea. The idea of one-credit courses increased the complexity of tracking student progress, and challenged the records processes at all partner universities.

By 1998, the four-year-old coalition was facing a crisis of trying to implement innovative ideas within cultural structures that resisted change. While the coalition never gave up the idea of experiential education, it began to focus more and more of its effort on creating computer-based instructional modules. Despite the emergence of the world-wide web, Greenfield chose to invest its development effort in proprietary multi-media software to support learning. As web technology began to explode in capability, Greenfield found itself in a position with legacy educational materials supported by a technology, which made maintenance of learning tools very difficult.

In 1990, the Greenfield Coalition realized that it had lost its unique focus on learning driven by real manufacturing experience, and that many of its learning products would not be competitive in the emerging web-based learning environment. The Coalition began to reexamine its mission, and to develop strategies to support that mission:

Greenfield Mission

Establish a new paradigm in manufacturing engineering education that integrates actual manufacturing experiences into the academic program.

Develop learning products to support this paradigm.

Deliver the new program to Candidates at the Focus:HOPE Center for Advanced Technologies.

Transfer the Greenfield paradigm to our partner universities, industry, inner city training and education centers, and the larger manufacturing education community.

As Greenfield retargeted its strategy to frame learning in terms of real-world manufacturing applications, the Focus:HOPE Center for Advanced Technologies became a springboard for the coalition to create reality-based learning activities. Greenfield defines reality-based learning as a problem-based approach in which the problems are real manufacturing applications. The new strategy aided the coalition in addressing its relevance to campus-based courses; Greenfield web-based learning products could bring Focus:HOPE's manufacturing facility into traditional classroom, enriching learning for the campus-based manufacturing student.

LEARNING PRODUCTS TO SUPPORT MANUFACTURING EDUCATION

The re-focused Greenfield Coalition has created a new educational experience not encumbered by legacy systems, which is founded on the integration of academic studies and real-world manufacturing applications. The Greenfield vision leverages technology to enhance and accelerate progress toward the degree. Greenfield has implemented a demonstration pilot at the Focus:HOPE Center for Advanced Technologies. In this setting, partners work cooperatively as a virtual university to deliver engineering and engineering technology degrees to a student body composed of 95% underrepresented minorities. With 120 students enrolled in the Greenfield-Focus:HOPE education programs, the student body represents the largest African American manufacturing program in the United States.

New manufacturing degrees have been introduced at the University of Detroit Mercy and at Lawrence Technological University. In addition, Wayne State University is adopting Greenfield courses to support its program in Manufacturing Systems offered in the Department of Industrial and Manufacturing Engineering. Lehigh University is using Greenfield courses and building new honors programs framed around the Greenfield strategy for experiential education. The degree programs at Focus:HOPE are fully institutionalized and supported by the degree granting institutions. NSF's funding of the Greenfield Coalition has leveraged significant extramural funding from the Ford Motor Company and the Society of Manufacturing Engineers to transfer the Greenfield paradigm to the UDM and Lawrence campus environments.

Greenfield learning products support these programs. They are characterized by

- A set of learning activities driven by real-world applications, which support learning in manufacturing engineering and technology.
- Packages of learning activities dynamically configured into sessions, modules, and courses.

Although most Greenfield courses have been first implemented for use in the very unique environment at the Focus:HOPE Center for Advanced Technologies, the design and structure of Greenfield learning components provides an ability to access an individual activity, or sets of activities packaged into a session or a concept-framed module. These learning objects can be viewed through the Greenfield Learning System, or they can be linked to another *Learning Management Systems* such as Blackboard or Gradepoint. They are publically available on Greenfield's website to as a resource to support education programs in manufacturing.

Greenfield Strategies

- Greenfield frames learning in terms of real manufacturing applications.
- The design of Greenfield products supports change in the culture of the classroom and enhances student learning.
- Technology supports collaborative development, an ability to reuse and repackage learning, and enables widespread dissemination.

During the first five years of funding, Greenfield completed development of 110 credits supporting foundation courses including: Communications, Liberal Arts, Mathematics, Engineering Science, and Engineering Fundamentals. For example, a set of workbook materials was developed to support instruction in mathematics, and Greenfield created Computer-Based Instructional (CBI) materials to support courses in the engineering sciences. Many of these tutorials are used by faculty today to support course delivery both at Focus:HOPE and in on-campus courses. Other efforts concentrated on the development of materials to support learning in the real-world environment of the Focus:HOPE Center for Advanced Technologies. Our courses in Communications, for example, modified traditional campus-based approaches to embed learning within the work environment of the Candidates at the Center for Advanced Technologies. As an example, writing assignments requires the learner to compose memos to his/her supervisor regarding a production issue within the Center for Advanced Technologies. Our course *Ethics in Industry* developed extensive resources available as computer-based documents supporting learning.

In the second five-year phase of the Greenfield NSF project, curriculum development turned to the core of manufacturing education. Beginning in Year 7, products were created as web-enabled learning resources to support a blended learning environment. These resources were not intended to replace lectures and textbooks, but rather to supplement the classroom experience for faculty and students. During Years 7 to 9 Greenfield will complete 48 additional credits to support its programs. Greenfield's new web-based learning resources began being released in 2002. Tables I to III describe the release schedule.

A sampling of Greenfield's sharable learning objects includes: capital investment decisions to solve quality problems in a production facility, the modeling of human/machine interaction, and a case study which integrate design and manufacturing for a tie rod assembly of a military vehicle. By focusing on real-world manufacturing applications, learning becomes meaningful; students move from academic problem-solving to thinking skills which will prepare them for careers as manufacturing engineers.

TABLE 1
GREENFIELD COURSES AVAILABLE 2002

Engineering Economics I & II	Wayne State University, Snehamay Khasnabis, R. Darrin Ellis, Frank Plonka
FORMING TECHNOLOGIES I & II	Ohio State University, Taylan Altan
INTEGRATED PRODUCT REALIZATION	Wayne State University. Leslie Monplaisir
The Manufacturing Organization	Walsh College, Mike Wood
Manufacturing Systems I	Lehigh University, Emory Zimmers, Greg Tonkay
Manufacturing Case Studies	Lawrence Technological University, William White
Reconfigurable Machining Systems	University of Michigan, Elijah Kannatey-Asibu, Zbigniew J. Pasek, and Wayne State University, Donald Falkenburg
Case Studies: Statistics and Probability	Michigan State University, V. Mandrekar , Lal Tummala

TABLE 1
GREENFIELD COURSES AVAILABLE 2002

Operations Management	Wayne State University, Ratna Babu
Assembly Processes	University of Detroit Mercy, David Lee, Jonathan Weaver
Manufacturing Systems II	Lehigh University, Emory Zimmers, Greg Tonkay
Machining Processes	Michigan State University, Patrick Kwan
Thermoscience Instrumentation Grinder	University of Detroit Mercy, Mark Schumack, Kirstie Plantenberg

TABLE 3
GREENFIELD COURSES AVAILABLE 2004

Facilities Design	Wayne State University, Leslie Monplaisir
Joining Processes	University of Detroit Mercy, Shurva Dass
Manufacturing Processes	Lawrence Technological University, William White and Michigan State University, Patrick Kwan
Entrepreneurship	Walsh College, Mike Wood
Measurements and Instrumentation	(Lehigh University Emory Zimmers and Gregory Tonkay)
Mechanisms and Kinematics	University of Detroit Mercy, Nassif Rayess, David Lee and Wayne State University, Gene Liao

In order to give a flavor for the Greenfield learning products, we will give three examples of courses available on the Greenfield website.

Forming Technologies

Forming Technologies I&II was developed by Professor Taylan Altan at Ohio State University. This course series focuses on the selection, performance and troubleshooting of appropriate sheet and bulk metal forming processes on the basis of: product design, technology, equipment, tooling, lubrication, controls, sensors and process variables.

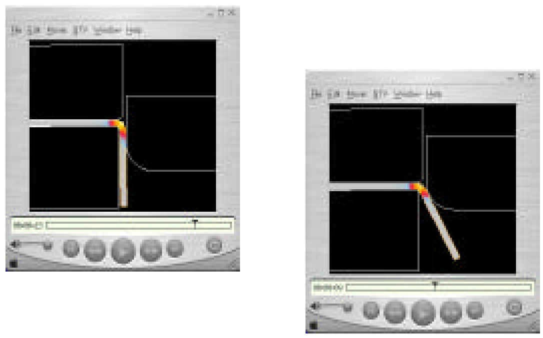

FIGURE. 1
SIMULATION OF SPRINGBACK EFFECT

Many diverse metal forming processes are required to produce a desired shape change. It is necessary to be knowledgeable about a variety of these processes in order to identify the best and most appropriate process for any given application. For this reason, these courses discuss both sheet and bulk metal forming processes.

Course materials include documentation depicting similar information for all processes so that a comparison of processes is possible. Some of this documentation, including text, tables, simulations and images, is accessible online. Technology is utilized to *visually* depict the differences among metal forming processes and equipment. For example, learners observe simulated equipment and examine whether particular equipment will work in the case they are investigating. Another example of the use of technology is to show a phenomenon that occurs during some metal forming processes. For example, consider the springback effect. Due to safety precautions and accessibility, it would be difficult to observe the springback effect firsthand. By creating this simulation, learners observe a simulation to see it in action. Following these simulations, learners discuss how springback could be prevented if it is an undesirable effect as well as determine if and how to anticipate the degree of springback.

Engineering Economics

Another course [2] currently available is Engineering Economics. Co-developed by Snehamay Khasnabis, R. Darrin Ellis, Frank Plonka of Wayne State University. This course deals with the study of economic principles and techniques needed to make engineering investment decisions. In the first course, fundamental concepts such as the time value of money and compounding serve as a foundation for making comparisons among alternatives using the EUAC, PWOC, IRR, and B/C ratio methodologies. The second course delves into more advanced concepts including depreciation accounting, tax implications and decision-making under variable conditions. These principles and techniques enable manufacturing engineering students to make prudent investment decisions in engineering practice while considering all possible long-term economic consequences.

This course series combines classroom experiences, requiring active participation and collaboration, and web-delivered activities. Students use a text, additional course materials supplied online as well as Microsoft Excel—an authentic tool for engineers involved with economic analysis, for many learning activities.

One use of Excel allows learners to see the difference among four depreciation methods and challenges them to select the most appropriate method for a given situation. A subsequent activity requires learners to choose the method with the most desirable tax implication.

As a capstone, students work collaboratively to resolve a real manufacturing problem in the Focus:HOPE Centger for Advanced Technologies. Interviews, a process map, product flow and cost data are among a large set of resources provided. Students are challenged to navigate through the resources in order to identify the source of the problem. Further, the learner must do an economic cost justification for any modification to the production system. A final report includes a sensitivity analysis and a decision tree.

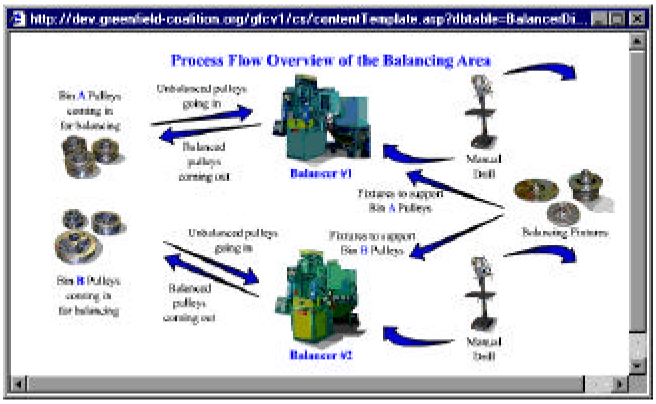

FIGURE. 2
PROCESS FLOW ENGINEERING ECONOMICS
CASE STUDY

Reconfigurable Manufacturing

Through a cooperative sharing agreement between the Greenfield Coalition and the Engineering Research Center on Reconfigurable Manufacture at the University of Michigan, two learning modules have been developed. The first module supports understanding the fundamental concepts of a Reconfigurable Manufacturing System (RMS) and the second module provides an introduction to the design of a Reconfigurable Machine Tool (RMT).

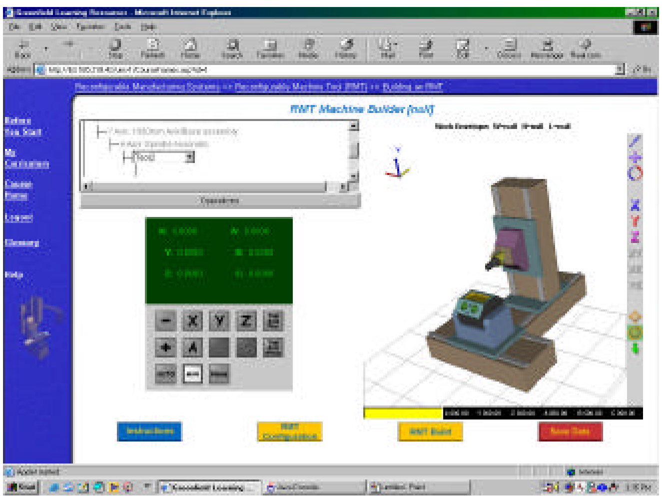

FIGURE. 3
RUNNING RMT IN VIRTUAL ENVIRONMENT

The focus of the first learning tool is to understand when RMT is an appropriate technology. The heart of the system is a simulation, which presents the learner with a family of parts, and a production schedule. The exercise involves comparing manufacturing systems based on (1) transfer line technology, (2) CNC technology, and (3) RMT. An economic model is built which allows the learner to evaluate these three alternatives, and to discover when RMT is a feasible, and preferred solution.

The first learning module is complete and is being used in the winter semester by professor Yoram Koren in his course on Computer Control of Manufacturing Systems at the University of Michigan.

This second learning module contains a virtual (Java 3D based) environment that allows the learner to build a RMT. Given the specification of a fixtured part to be machined, the learner determines the work envelope, the number of axes (linear and rotary) of motion, the spindle, and the adapter plates are specified. The process continues with design of the motion hierarchy and axis connectivity. An operational control panel is then configured, and the machine is simulated. This project is now completed.

These two modules are integrated in Greenfield's instructional program, and are starting to be used by the University of Michigan in their undergraduate and graduate courses and outreach programs for the ERC.

A description of other Greenfield Courses [3], [4] will appear in the 2002 Proceedings of the American Society for Engineering Education Annual Conference.

SUMMARY

The Greenfield Coalition at Focus:HOPE has created a learning system in which engineering education and practice are integrated, and students actively participate in their learning. We have created a "learning factory" at the Center for Advanced Technologies (Focus:HOPE)—a unique educational facility which is also a tier-one automotive supplier. Here, classroom and experiential learning are integrated in a real-world manufacturing environment. All Greenfield partners work together as a virtual university to offer degrees at the Focus:HOPE pilot. Greenfield's web-based learning tools draw upon, and are set in the manufacturing environment of the Focus:HOPE Center for Advanced Technologies. University partners not only participate collectively at the Focus:HOPE pilot, but transfer the Greenfield concept to more traditionally structured classrooms.

ACKNOWLEDGEMENT

The Greenfield Coalition is partially supported by a Grant EEC-9630951 under the Engineering Education Coalitions Program at the National Science Foundation. Focus:HOPE, our industry and academic partners have contributed valuable resources to support the development of Greenfield.

REFERENCES

[1] Falkenburg, Donald R., The Greenfield Coalition: Partnership For Change In Manufacturing Engineering And Technology Education, International Conference on Engineering Education, Oslo Norway, August 6-10, 2001.

[2] Plonka Francis E., Diane Schuch Miller, Syed Khusro Azmat, Pratap Srinivasa Murthy, Snehamay Khasnabis, and Richard Darin Ellis, *An Engineering Economics Case Study at the Greenfield Coalition*, Proceedings of the 2002 American Society for Engineering Education Annual Conference. (to appear)

[3] Mandrekar, V, R. Lal Tummala, and Kenneth Morris, Statistics For Engineers: Experiential Learning Approach, Proceedings of the 2002 American Society for Engineering Education Annual Conference. (to appear)

[4] Zimmers,Emory W. and Greg Tonkay, Computer-Based Learning Activities in Manufacturing Systems, Proceedings of the 2002 American Society for Engineering Education Annual Conference. (to appear)