Information Technology a Tool for Educational Reform: Lessons from the Greenfield Coalition

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Abstract *— Information technology has had an impact on engineering education and it will continue to be a significant tool for educational reform during the first two decades of the twenty-first century. This paper presents a vision of the use of information technology to support learning and describes the progress of the Greenfield Coalition in implementing technology and pedagogy to support IT-enhanced learning.*

Index Terms *— case studies, engineering education, information technology, internet, learning pedagogy*

INTRODUCTION

The use of information technology to support learning began on the Urbana campus of the University of Illinois in the 1960s. PLATO was developed as a time-share system, which used a special language called TUTOR to author and deliver learning materials to students located in a single classroom. With the advent of desktop and laptop personal computers, a large number of authoring systems were introduced to the market to support learning using CD media. College texts began to include a CD with dynamic images and other tutorial material. The advent of the internet created a new way to distribute materials over the worldwide web. New technologies supported new approaches to learning, which did not have any analog in the textbook paradigm. In the past few years, the emergence of *Learning Management Systems*, such as Blackboard, have sparked a burgeoning array of learning materials on the World-Wide-Web. The Greenfield Coalition began developing learning resources just as the internet was beginning to emerge. The first courses Greenfield developed were patterned after the CBI (computer-based instruction) model and were distributed using compact disc technology. At the time, the paradigm focused on creating hyperlinked digital media. Pedagogically, it was not substantially different from the *textbook as learning resource* paradigm. In the year 2000, the Coalition began to focus on using the internet to provide a much more dynamic environment in which to build and distribute learning resources. In the past four years, there have been substantial changes in *Information Technology* and *Web-Based Learning Technology*, which have revolutionized our approach to the development of learning resources. For example, in one two-year period, we adopted three different technologies to render three-dimensional graphics on the web. We went from displaying mathematical equations using GIFs to an implementation of MathML enabling an object description of formulas and opening the door to the active manipulation of mathematical equations on the web.

This paper begins by summarizing two National Academy of Engineering workshops targeting future development of IT technology and its application to enhance learning. It then moves to show a few examples of how Greenfield uses IT to support emerging paradigms of learning, and how new IT will enhance our ability to do this. By itself, information technology does little to enhance learning. Greenfield's experience has shown that combining IT with emerging paradigms of learning can deepen comprehension and enhance decision-making skills of the engineer-in-training. In the second to the last section of this paper, we will introduce to a few human factors emerging from our research, which deal with aligning teachers and students with technology in support of learning. The paper ends with a brief description of the NSF-sponsored Greenfield Coalition and the unique role it has played.

IT FUTURE

The rapid evolution of information technology poses opportunity and threat to the use of IT to support learning. The opportunity is clearly enhanced technological capability. Today, for example, math software like Mathematica is available in a web environment. Each year memory, bandwidth, and application software expand. With this growing capability comes a need to make decisions about which path to follow. Today's hot web-technology may not exist in two years. Since there is a cost to develop materials, what strategy should be used when new technologies rapidly replace older ones?

There are many studies targeting the future of Information Technology and its impact. In order to frame the discussions presented in this paper, two quotes are presented from the section *Technology Futures* of a 2002 report *Preparing For The Revolution: Information Technology and the Future of the Research University* [1] published by the National Academies Press.

> *"From the average user's point of view, the exponential rate dictated by Moore's Law will drive increases of 100 to 1,000 in computing speed, storage capacity, and bandwidth every decade. At that pace, today's $1,000-notebook computer will, by the year 2020, have a computing speed of 1 million gigahertz, a memory of thousands of terabytes, and linkages to networks at data transmission speeds of gigabits per second."*

> *"…the world of the user could be marked by increasing technological sophistication. With virtual reality, individuals may routinely communicate with one another through simulated environments, or "telepresence," perhaps delegating their own digital representations—"software agents," or tools that collect, organize, relate, and summarize knowledge on behalf of their human masters—to interact in a virtual world with those of their colleagues. As communications technology increases in power by 100 fold (or more) each decade, such digitally mediated human interactions could take place with essentially any degree of fidelity desired."*

The NAE workshop *Information Technology (IT)-Based Educational Materials* [2] translated this future vision into the framework of teaching and learning. The workshop report described the current state of the use of information technology in the support of learning.

> *"Many STEM educational programs and institutions have been involved in projects to improve teaching and learning through the application of IT. The resulting IT-based learning materials have proven to be adaptable and dynamic, and in many cases they have enhanced the educational process. A growing number of people are involved in the development of IT-based educational materials. The landscape of STEM education is now dotted with islands of innovation—isolated areas where IT-based materials are being used effectively. However, not all innovations have led to more effective learning because these materials are often used by limited numbers of users. Thus, opportunities for synergy, discourse, and exchange—steps that often lead to improvements in next-generation products—have also been limited. Impediments to realizing a desirable environment for IT-based educational materials are complex… technology and tools, infrastructure, content and pedagogy; and human, cultural, and organizational issues… are inextricably intertwined."*

A future vision of an IT-transformed educational environment was constructed from the workshop discussions. The participants summarized the future in three broad categories

- Technology and Tools Infrastructure
- Content and Pedagogy
- Human, Cultural, and Organizational Frameworks

A future vision summarized the discussions:

> *"A robust suite of modular, IT-based resources supports a dynamic, distributed, and flexible learning environment. Built on open system architectures and machine-understandable semantic models, these resources are interoperable, sharable, easy to use, easy to modify, and widely disseminated; they underpin a vibrant teaching and learning community and enable a sustainable ecology for continuous improvements in educational practice. A rich array of technologies and approaches form the scaffolding for further modifications to the learning environment, enabling the optimization of educational practices for their effectiveness rather than for simple efficiency. The elements that support the learning environment integrate advanced knowledge about technology, people, processes, and organizations."*

Key statements about the future are presented in the following quotes:

> *"In the world of IT-transformed education, advanced learning objects are the building blocks of IT-enabled educational materials. Advanced learning objects will be developed based on community-defined requirements for a services-based architecture that supports varying levels of interoperability and emphasizes operational communication and data exchange."*

> *"STEM educational practices will have a learner-centric orientation and will reflect advanced, evidence-based knowledge on learning and cognition."*

"IT-based teaching and learning practices will be generated by an active community of authors and users who create, share, and modify IT-enabled educational materials. This community will embrace a scholarship of teaching and learning and will have a continuing goal of advancing learning."

"The dissemination of IT-enabled teaching and learning resources will be supported by a novel legal framework (e.g., open licenses and attribution systems) that promote creation and sharing, while maintaining incentives for authors (including individuals, teams, and institutions) to create and distribute or assemble and reuse high-quality learning materials."

IT SUPPORTS PEDAGOGY

One of the lessons learned at the Greenfield Coalition was that while information technology opens new avenues to enhance learning, technology is not a silver bullet, which by itself promotes learning. We asked the question: What do we want to accomplish by using information technology as a support to the learning process? The answer emerged from the Greenfield values and beliefs about learning.

- Learning is a shared responsibility between learner and teacher.
- Faculty play a key role guiding students in the learning process.
- Learning is made real if it is integrated with real-world experience.
- Learners must prepare to engage in classroom experiences.
- Learning is a social process, which requires interaction with mentors and peers.
- By actively participating in their learning, students achieve deeper understanding and enhanced skills.

Information technology must be leveraged not for its own sake, but to be supportive of a vision we have of the transformed classroom. While there are many issues we might consider, we will illustrate two here.

Engage Learners in Decision-Making Framed in Real-World Environments

In the future, improved hardware and software will enhance simulated virtual environments in which the learner can become immersed in the problem solving and decision making experience.

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 [3] 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 [4].

Today we can provide an environment in which computer-based resources allow learners to access real data and participate in case-based learning [5]. For example, students can explore a real factory of a tier-one auto supplier, accessing process plans, production data, scrap reports, and interviews with key personnel. In the future, improved hardware and software will enhance simulated virtual environments in which the learner can become immersed in the problem solving and decision making experience. Interviews will not be canned, but can be constructed by the learner and intelligent computer systems will provide responses learner inquiries.

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].

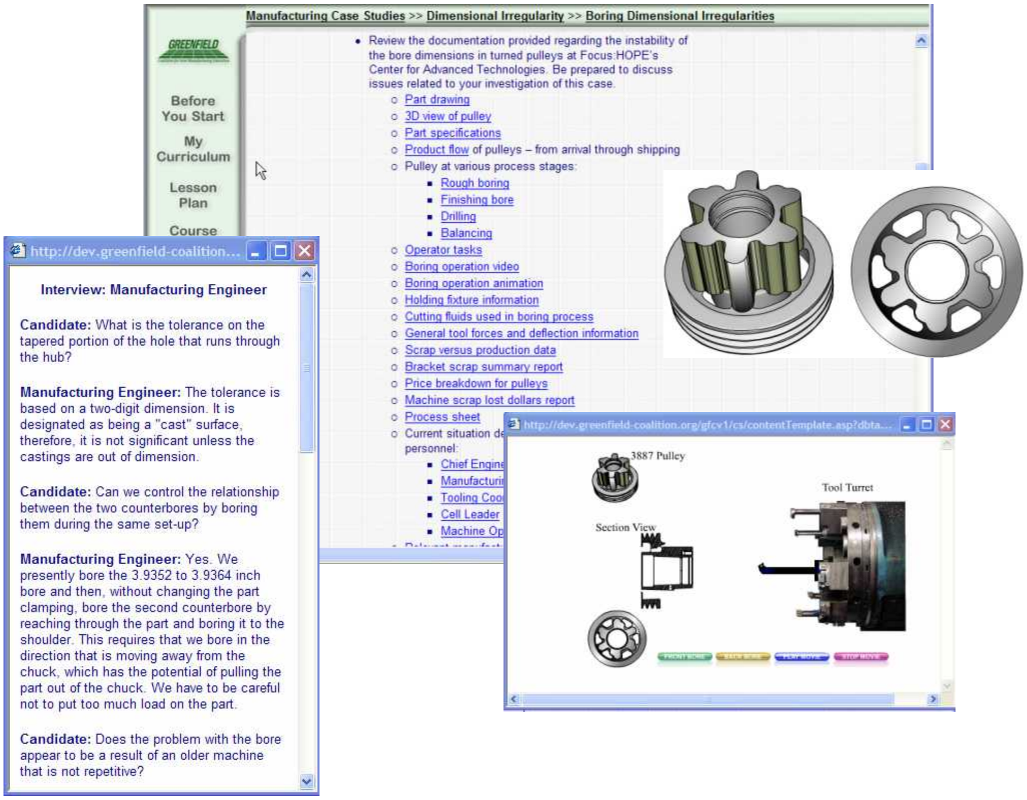

FIGURE 1: COMPUTER RESOURCES SUPPORTING A GREENFIELD CASE STUDY

Use Simulation to Strengthen Understanding and Decision Making Skills

The future will bring improved methods to simulate real-world systems. Those simulations will be easier to construct, encapsulate very real views. The technology improvement should be used early in the career of the student engineer not to teach modeling, per se, but to enhance the ability to make engineering decisions.

Many of us feel very comfortable with teaching computer simulation to enhance problem-solving skills. The problem is that we most frequently focus on the development of computer models to represent an engineering component or a system, and we frequently neglect the reason we build models—to enhance the ability of our students to make engineering decisions.

Manufacturing Systems is a sophomore-level Greenfield course developed by Professor Emory Zimmers at Lehigh University. Learners are introduced to *Colebee Time Management, Incorporated* a firm that has determined that fast order fulfillment is one of their competitive advantages. As they move to producing more customized planners and calendars, additional analysis of the printing cell area is needed. Larger varieties of product and smaller batch sizes have slowed down the printing area.

> *When a new printing job arrives, it waits for the current group of jobs to finish. After all jobs in the current group are finished, the new jobs that are waiting to be printed are lined up in a specific order. The charge to the learner is to improve the operational efficiency of the printing cell by minimizing the makespan. Makespan is the time it takes to complete the entire group of parts that are ready to proceed into the process. A simulation model of a printing cell is provided. Learners use the simulation model to predict operational improvements to the system. Learners are told that Makespan should be their primary focus, but they may want to observe the queue sizes and the average time jobs are in the printing area. Learners are told that they can manage three key parameters: (1) Number of work centers, (2) Hours per shift, and (3) Shifts per week*

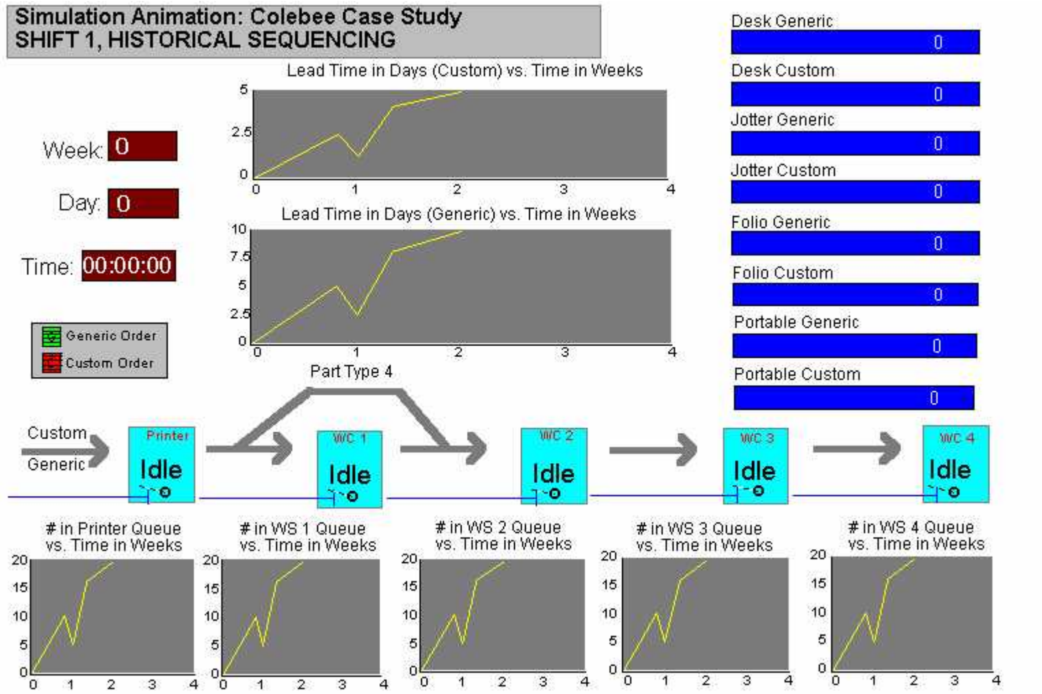

FIGURE 2: SIMULATION ANIMATION: COLEBEE CASE STUDY

Key questions asked of the learners are:

- What strategy did you use to select the parameters to improve operational efficiency?
- If you could modify the simulation model to allow more parameters to be changed, which parameters would you choose to add? Explain your answer.
- Which combination of parameters optimized the manufacturing plant's operations? Explain your answer.

This case not about building a computer model, but it is about making engineering decisions.

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Learning Objects

The Greenfield Learning Object Model (LOM) recognizes a hierarchy of objects [7]. The heart of the Greenfield Product is a learning activity, which focuses on the action of learning. These activities are dynamically configured into sessions, modules, and courses. In Greenfield parlance:

Activity: Greenfield learning activities include discussions, computer-based animations and simulations to aid learning, mini-lectures, cooperative problem solving-exercises, etc. In other words-- the action of learning.

Session: Groups of activities are packaged to in a learning session. Greenfield does not define a time frame for a session. It is simply a convienent grouping of activities.

Module: A module is a concept-frame packet of learning. A module contains one or more sessions.

In Greenfield's course *Engineering Economics*, *Depreciation Accounting* is a Module. *Depreciation Methodologies* and *Income Tax Impact* are Sessions. Within the Session, *Income Tax Impact*, there is an interactive e-learning Activity entitled *Income Tax Consequences*.

An important reason for developing this hierarchial structure has been the realization that most faculty want to structure their own course. While they may be interested in borrowing some "neat" learning activities, each of us desires to package learning in our own unique way. Each of the learning activities is an individual entity stored in a database. Using a methodolo… ing mo… , we de… f the lea… ibe its content using XML … ivity in … L temp…

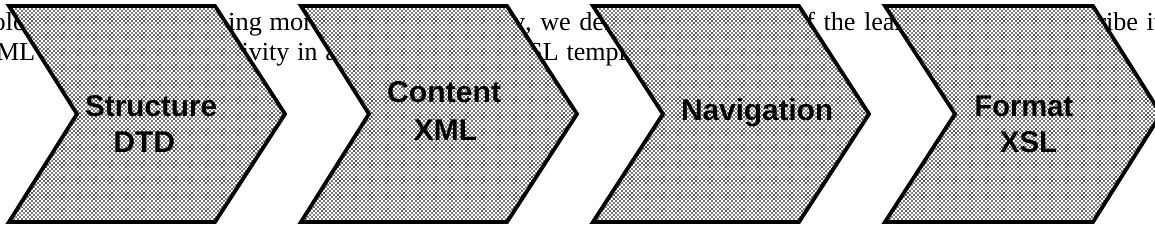

FIGURE 3: IMPLEMENTING GREENFIELD OBJECT STRUCTURE

Courses contain links to their modules which are contained in the content for the course. Similarly, links from a module (which contains its sessions) are a part of the module content. Navigating up the hierarchy is an entirely different matter. If an activity is shared among severeal different sessions, how do we know where to navigate? If I want to borrow a single learning activity or a session of related learning activities, I do not want to have links to the original author's course. The way in which we have handled that is to restrict all links embedded in the content to be down the hierarchy and to be limited to one level. Links up the hierarchy are constructed differently. If a course is shared, then the uplinks are displayed on a toolbar depending on the user's position in the hierarchy. An example is displayed in Figure 4. If the user is currently accessing an activity, the toolbar would look as depicted in Figure 4. If, however, the user is at the session level, the toolbar would show Course >> Module.

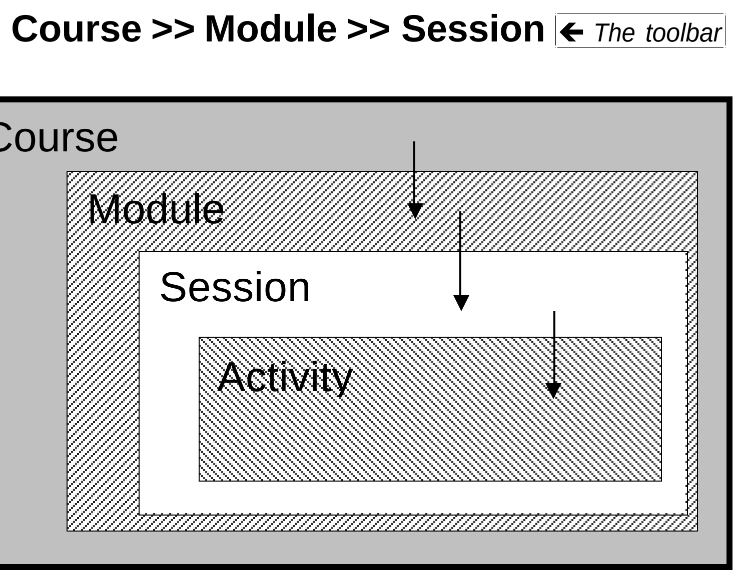

FIGURE 4: STRUCTURING NAVIGATION IN A GREENFIELD COURSE

As part of the definition of the learning objects, we include objectives. Objectives are defined at a course level (we call these terminal objectives) and at module and session levels (we call these enabling objectives—objectives which support the terminal objective of a course.) Because we have included objectives within the object structure of a course, it is straightforward to produce an tree of learning objectives for the course. Greenfield defines two additional levels in its object structure: program and knowledge area. A knowledge area is a group of courses which share certain instructional objectives and outcomes. For example within a program targeting manufacturing engineering there are typically courses which focus on manufacturing systems and courses which target manufacturing processes. Defining programs in this manner provide an ability to develop a tree of objectives for an entire program. Treating prerequiste knowldege as a child object of a course, for example, allows us to better manage requirements for a full curriculum. Metatags embedded at each level of the hierarchy define content, special technology support required, etc.

Importantly, authorship and intellectual property rights are embedded within the objects. Thus, a multiply-authored document can be created by referencing different objects. Data about use restrictions and ownership are drawn from the database and displayed within the composite document.

CHANGING OUR CULTURE

Technology provides one platform for reform of our educational processes. That technology cannot make a difference if people and organizations don't adapt and change. The same technology can have two different impact scenarios depending upon the way in which it is introduced and managed. The classroom is a milieu in which three cultures negotiate—student, teacher, and university. The behavior of each group is driven by its own beliefs and values. Often, students are comfortable with the non-threatening environment of the passive lecture; they may resist changing the pedagogy—the rules by which the classroom operates. Non-cooperative students may easily sway a teacher with modest interest, but little resolve, in an effort to introduce educational reform. Attitudes of the senior faculty embedded in institutional guidelines for promotion and tenure may create a force, which resists change. Beliefs, values, and behaviors are not imbedded in a causal structure. Rather, they feed on each other. Educational reform, therefore involves a continual negotiation among these groups and a gradual evolution of beliefs, values, and behaviors across the learning community.

Greenfield is in the final phase of a research study targeting the factors, which enhance, and those that impede the diffusion of enhanced learning technologies. Each classroom is an arena in which the culture of learners and teachers come together and negotiate their beliefs, values, and behaviors. Change in the educational process is not simply the adoption of information technology, but it is how our approaches to learning change and are enabled by that technology. Does the technology give us better means of enhancing modern approaches to learning [8], [9], [10] or does it provide a diversion from accessing deeper understanding and improved decision making ability of the future engineer.

The Greenfield Coalition and Focus: HOPE

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. The impetus for the Greenfield project was the sense that most academic studies in manufacturing engineering were devoid of real manufacturing experiences. [8] The idea for the coalition was born in Focus:HOPE, a human and civil rights organization located in Detroit, Michigan.

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—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 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.

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