Agile Learning for Agile Manufacturing: An e-Learning Model

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ABSTRACT

In this paper we discuss the need for bringing the traditional training concept of the *apprenticeship* that has been the educational legacy of the manufacturing industry, into the 21st Century through the integration of *knowledge and content management* with *collaboration technologies*. We discuss development of an specialized e-learning approach to address *systematic workforce development* through *online apprenticeship and training* as a necessary training paradigm shift to significantly improve the skills level of the American manufacturing workforce by applying well-established *online constructs* for *content, instruction,* and *assessment.* Within that framework, we propose to explore needs to: a) define the requirements for deploying current Internet collaboration technologies in the manufacturing domain, b) assist the manufacturing industry in systematically connecting the workforce of the future to on-line resources and masters, c) create realistic apprenticeship relationships outside the assembly line and shop-floor, d) help create new pre-job training or post-secondary manufacturing skills development programs, and e) help enhance recruiting opportunities for industry. The paper is focused on the basic need for developing a new *(online) manufacturing training methodology* in order to aid the American manufacturing industry to recruit, train and build the manufacturing workforce of the future.

INTRODUCTION

> ***"Tho Millard by his owne consent is released & discharged of Mr. Pinchons service this 22. of May 1648 being 4 months before his tyme comes out, in Consideration whereof he looses the 40s in mony wch should have bin pd him, but Mr. Pynchon givith him one New sute of Aparell he hath at present. — Thomas Millard 22nd of May 1648"***
>
> ***"Despite the fact that more manufacturing today is done in clean environments where workers program computers to run machinery instead of operating it themselves, the image persists that manufacturing is a dark, dirty place that's unsafe and involves a lot of physical labor. — industryweek.com May 7, 2001"***

The research goal of this paper is to explore how to bring the traditional concept of the *apprenticeship* that has been the landmark of manufacturing training, into the 21st Century through the integration of *knowledge and content management* with *collaboration technologies*. In the

latest manufacturing innovation RFP, The National Science Foundation (NSF) recently identified three areas for improving the skills and knowledge of the American manufacturing workforce: *content inclusion, intelligent instruction, and assessment technology*. In terms of today's e-learning and Web-based technologies, it is possible to coordinate those three components of (online) manufacturing training through the design of a *portal* to simultaneously address *systematic workforce development* through *online apprenticeship and training*. Such system would embody what we believe can become a *systemic apprenticeship support system*, specifically by mapping *automatic content creation, knowledge management*, and *authentic assessment*, the three research areas targeted by NSF.

Through a portal, well-understood instructional technology models can be mapped to the practice of the apprenticeship in order to create a new manufacturing training environment and a new (online) manufacturing training model. Such portal can help industry to fully utilize the potential of e-learning and Web technologies to proactively recruit and build the manufacturing workforce of the future. For the purpose of this paper, the discussion focuses on an *E-PPRENTICESHIP MODEL (EPM)* and it is aligned with the American automotive industry. The model provides insight on how e-learning and Web-based technologies can be used and scaled up to serve the automotive industry at large and the manufacturing industry in general in order to speed the development of an *advanced manufacturing workforce of the future*.

The **practical merit** of EPM is to help improve workforce capabilities and American manufacturing competitiveness. EPM is envisioned as a real-world, master-centered, e-learning system that both reinforces and extends hands-on training. EPM provides a testbed scenario for developing best practices in this specific area of training based on e-learning, and can potentially be used to identifying standards for manufacturing e-learning.

To address these goals the research is guided to:

- Create an interactive portal that structures masters' and apprentices' access to apprenticeship situations and training resources.
- Map the apprenticeship scenario to existing automotive industry training resources.
- Identify and include relevant high-quality media resources as auxiliary training content.
- Identify and/or create hands-on simulations that align the roles, goals and situations of traditional shop-floor apprenticeship as new integrated resources.
- Identify and/or create work-place scenarios and accompanying simulated hands-on activities and/or computer-based hands-on simulations.
- Train masters and apprentices on the use the portal to promote master-based and simulation-based training.

The portal component of EPM can also be used to help organize focus groups, assessments and interviews to evaluate the usability, effectiveness, and the potential for:

- Long-term sustainability of the approach/solution
- Extension to other manufacturing industries
- Development of human capital for the manufacturing industry

With those goals in mind, we suggest that the inherent value of a coordinated dedicated e-learning approach to manufacturing training can have profound social, economic and educational impact.

The **social impact** of EPM is meant to be helping to create a technology-based apprenticeship culture to support and enhance the traditional shop-floor, hands-on apprenticeship model that today serves the manufacturing industry so well; and, to provide access to knowledge about industry jobs and training for those jobs outside the localities where the industries reside. A systematic, online approach to manufacturing training will create new opportunities for both employers looking for manufacturing talent and workers looking to enter or retrain in the manufacturing industry. This is so because it will connect people who may have no knowledge of the existence and details of specific jobs, and it will help industry recruit from among potentially competent Americans who need jobs and have an affinity with specific manufacturing industries. Lack of access to information and training resources is a barrier that can be overcome with the use of innovative technology.

The potential **economic impact** of the approach/solution rests in its potential ability to address unstable industry situations by workforce retraining and job pools recruiting avenues for aligning changing industry needs with the workforce. Lack of access to knowledge about jobs prevents potentially capable workers from competing for jobs that may be available or emerging. EPM can also help to overcome social barriers by providing an apprenticeship environment to potential workers before they enter a given industry, and by nurturing the manufacturing culture as a key to sustaining the industry through a combination of interpersonal activities such as discussion forums, two-way videos, application sharing, and scenario modeling. EPM can serve to support workers in the development of skills that they may not even know they possess and train for jobs that they may not even know exist. EPM can avert loss of talent, time and effort to help industry become more flexible with respect to human resources.

The **academic and basic research value** of needed EPM research is in its focus on pedagogy to guide manufacturing training, and more specifically to connect knowledge of *agile learning* with exploratory ideas for *agile manufacturing*. With this pedagogically focused model, we hope to promote a research path that connects *designer automotive solutions* (e.g., the just-for-me three-day car) *with just-in-time factory-floor training*, thus creating a new research agenda for industry and academia that is centered about two groups of people: workers and consumers.

We propose that the concept of EPM as a model for taking the manufacturing apprenticeship out of the15th Century and guide it into the 21st Century:

BACKGROUND

It has been suggested (by NSF) that no prior research or systematic knowledge gathering and sharing process exists that can be used to design or evaluate manufacturing training research targeted at national competitiveness. That premise presents an opportunity to not only advance EPM research, but to launch EPM as fundamental needed reform in manufacturing training. Since there is no prior funded research or research funding precedence, the problem can be defined a priori.

While there are examples of successful technology-based manufacturing training practices, the research that supports these practices is spread across many domains. This makes it presently difficult to derive optimum benefit from prior practices for a given complex industry, such as the automotive industry. Focus on one industry is necessary to develop best practices. Industry-specific research is needed to help outline strategies to explore theories and technologies that can be harnessed to address the general problem of manufacturing training as the national imperative that it already is. Research focus in many areas is needed to *change the state-of-the art in manufacturing training in general,* an ambitious goal that must be undertaken if we are to avert the impending demise of the American manufacturing industry. We therefore view the needed research as a socio-academic study contribution to the national labor agenda.

EXAMINING THE APPRENTICESHIP MODEL

The concept of universities and all forms of "professional" training have in common the apprenticeship model as their sole pedagogical root. Yet, it took the Industrial Revolution and competition for manufactured goods to launch the culture of apprenticeship as the centerpiece of economic development in Europe. During the latter part of the 19th century international competition in manufactured goods put manufacturing training into governmental focus. Competition from emerging economies challenged the established industrialized world. Later the World Wars impacted manufacturing training in a multitude of ways, most notably with the induction of women in the modern manufacturing workforce both here in America and in Europe. Post-war reconstruction, to this day, anywhere in the world, calls for renewed efforts to improve the efficiency and rapidity with which to train a diverse workforce, (1).

Research in the history of manufacturing training seems to indicate that established forces in manufacturing infrastructure development, most notably in the U.K. and the U.S. start to cycle into serious workforce training deficiencies that allow windows of opportunities for developing economies to gain the upper hand in the manufacturing industry. While the exposures have been attributed to *cheaper labor overseas*, labor leaders are quick to point out that there's no shortage of workers at home who are willing to work on U.S. shop-floos. In America, both arguments to justify and condemn the exportation of our manufacturing jobs are rational; because, *prioritizing growth and economic development* is no less important a national imperative than *reducing our unemployment rate*. The new challenge is in how to strike a socioeconomic and cultural balance through policy modifcations driven by the availability of e-learning.

NEW TRENDS IN TRAINING POLICY

Shop-floor training is no longer done "on the floor," and organizations dedicated solely to educating the manufacturing workers are modeling themselves after virtual universities. An example is the Tooling University (2), which offers online courses prepared or supervised by *manufacturing experts*, but does not provide the kind of one-on-one learning paradigm that is known to not only foster new generations of skilled workers, but also nurture the culture of *slowly acquired special skills*. Even with the addition of *accountability* critical in the academic paradigm, online training alone will always fall short of the requirements for the development of those special skills that the apprenticeship model provides: *watching, doing and learning from experience.*

Other initiatives compensate for these deficiencies. The State of Oregon, for example, combines opportunities for continuing education and job training with employer intervention, (3). The 21st Century workforce will require the traditional academic accountability complemented with the also traditional apprenticeship form of training. Even then, both of these models fall short of the emerging need to prepare or retrain our workforce for the advanced and technically complex manufacturing jobs of the future in order to increase employment mobility, minimizing unemployment. We can do that if we systematically:

1) introduce knowledge management into the apprenticeship process; and,
2) incorporate the apprentice model into the e-learning approach.

This calls for the application of a special kind of e-learning and the use of special kinds of new information and knowledge management technologies, as well as the development of a dedicated manufacturing e-learning infrastructure. Next generation manufacturing e-learning should support the needs of the industry and elevate our manufacturing workforce at large to a higher professional level.

ON THE NEED TO MAKE THE MANUFACTURING APPRENTICESHIP A REALISTIC JOB TRAINING OPTION FOR THE 21st CENTURY AMERICAN WORKFORCE

According to the U.S. Department of Labor, the overarching workforce issues in the advanced manufacturing industry are: *retention, recruitment, education and training*, (4). The National Association of Manufacturers identified, as the most pervasive problem that the manufacturing industry faces now, the need for workers skilled enough to work in the manufacturing jobs of the 21st Century. Exacerbating that problem more than 76 million baby boomers will retire over the next 20 years, but only 46 million Generation Xers will take their places. American manufacturers face a severe shortage of men and women to run tomorrow's factories and offices, (5). Modern manufacturing has created a great demand for highly trained workers, but the most protracted aspect of the problem that employers face is the *lack of new-skills workers to operate their high-tech manufacturing plants.* Even during the recent recession, 80% of manufacturers said they had a moderate to serious shortage of good production applicants, not just engineers, but also of advanced manufacturing workers. Conflicting with this problem, months of *on-the-job training or combined work experience and formal classroom instruction* are typically necessary to prepare the advanced manufacturing workforce. Formal and informal apprenticeships may last up to 5 years. In this climate, pre-employment testing material and aptitude assessment are luxuries that require balanced strategies for *human capital development*. As we refine *public policy for workforce investment*, those very issues are key factors in determining our ability to build the 21st Century manufacturing workforce, (6).

When Manufacturing Jobs Disappear…

> ***"In 1980, Scotland, whose primary place of employment was the factory, lost one-third of its manufacturing jobs, 300,000 almost overnight. With that disappeared the most important educational opportunity for a majority of the population: the apprenticeship."***
> **[http://www.findarticles.com/p/articles/mi_m4467/is_8_55/ai_78364220]**

Scotland's independent government merged two cabinet posts, the Minister for Enterprise and the Minister for Lifelong Learning, (7); this asserted on that nation's commitment to link jobs with skills, thus supporting the notion that education (training) is the key to economic development. But it also signaled a national need to make lifelong learning the most significant policy-making position, not surprisingly because Scotland has a rich history of making education a national priority, (8). Today, in Scotland, the responsibility of sustaining lifelong workforce training programs is shared.

- Government is the primary economic development organization.
- Industry is directly involved in the creation and deployment of lifelong learning.
- Consortiums and partnerships between the public and private sectors, often involves academia in order to extend lifelong learning and e-learning opportunities.

This model would be easy to replicate in the U.S. with impetus from government, as has been the case with other national impact imperatives. In order to do that, a technology strategy has to be put in place that fits the lifestyle of the American workforce. Social, educational and technical issues have to be taken into cosideration as a well as the size of the American workforce. In addition, it makes eminent sense to leverage other infrastructure building investments, such as the Internet and the virtual university. Economies of scale come from integrating new paradigms.

When Education is no Longer the Key to Economic Development…

Myron Weiner led the way for understanding the intricate role that education plays in economic development. His writings were visionary. Today, however, a different vision is required. India, the object of Weiner's intense social, political and economic focus, lends a light into the problems that we now face, problems that defy brilliant vision and become simply counterintuitive. A country that spends 3 percent of its GNP in education, (9) creating what UNESCO calls a "barefoot college generation," (10), now stands to shake the foundations of the American economy by providing a better trained, more responsive Information Technology (IT) workforce. Mexico, where social and political instability interrupted the ambitious process of mandatory education, meant to model the U.S., has "stolen" our manufacturing industry and turned the key on our economic trade agreements. Comparative policy analysis indicates that America "lavishes" on education, (11), yet the results are now reversing our own economic development. We are now faced with the demise of both our manufacturing and IT industries; the competition seems to come out of the blue. Have we shot ourselves in the foot? What went wrong with Weiner's vision? Is education no longer the key to economic development?

THE CONCEPT OPF DIRECTED ECONOMIC DEVELOPMENT

The concept of the education-economy *double helix* (12), where complementing changes in our educational system with changes in the workplace becomes the unquestionable hallmark of industrialization must be revisited in light of new economic realities. Industrialization leapfrogging in the absence of mandatory education and large government budgets for education is a reality that defies logic and studied research. New research is needed to help understand what drives these realities, and more importantly, to help reassess our industry priorities. It would be unconscionable to simply adapt to the flow of events without understanding where we are being

led by them. Nevertheless, some of the established premises hold true, even within the new realities, but with perhaps different implications. For example the facts that:

1. Changes in the workplace make education unconnected to the skills needed to perform at work - may still be true, but for different reasons, such as the fact that some important jobs are simply beyond our borders.
2. Schools from K-12 to corporate training often fail to apply what is now known about how people learn most effectively – which may still be true, but may be a redundant concern since brute force rather than pedagogy may be transforming industry training.
3. Efforts for strengthening our educational system so that it conforms to the ways that students learn best also serves to directly enhance our ability in preparing students for the transformed workplace, but may have less impact on the larger pool of emerging jobs, than on the existing American workforce.

The overarching suggestion is that the vast majority of future jobs, in IT and manufacturing, are being outsourced because the economy depends more on finance than on education. This is a difficult problem to solve from the human capacity perspective, because: what do we need to prepare our existing workforce to do? The answer, we believe, is *learning transitions***.**

AN INTEGRATED TRAINING COLLABORATION, CONTENT AND KNOWLEDGE MANAGEMENT, ASSESSMENT, RETENTION AND RECRUITING APPLIED TO THE MANUFACTURING INDUSTRY

There are many possible ways in which to introduce e-learning into the manufacturing industry, we have illustrate some. Beyond the obvious and typical there's a space that is geared at the future of the marketplace. Where we are taking manufacturing must intercept where we are taking education and training, not just e-learning. That requires that we modify or formulate new paradigms for e-learning and that we facilitate the implementation of those paradigms. For the particular research agenda that we have outlined, we find that the connection between the pedagogical concept of the agile learner, (13) first presented at by a White House Think Tank (14), and the industry trend of improving the workflow process with agile manufacturing, (15) again offer some intriguing possibilities – not yet explored in terms of new technologies.

Agile learning interlaces basic educational, social, psychological, and managerial issues within a well- grounded theoretical framework, which has been used by schools in Michigan, New Jersey, Florida, California, and Washington, D.C. and its constructs became key elements in the 1994 White House Report to the U.S. Department of Labor on the emerging needs of an *Agile Workforce*. But not until now, has the connection been made between this pedagogically grounded learning approach and manufacturing training. We see important parallels between agile learning and agile manufacturing in that both address outcomes and processes.

Modern information and communications technologies have created possibilities for just-in-time training that can play a major role in manufacturing training. Instructional technology has also advanced to the point where the concept (introduced here) of *just-for-me* training can become a useful reality. That is, the ability to match granular learning needs with instructional technology constructs in order to make specific real-time training possible. In the car-manufacturing scenario,

the assembly line can become a *designer operation* where both the product (of the manufacturing process) and the skills training required to manufacture the product are perfectly matched. By any standards, this approach maximizes not only efficiency, more importantly, human potential.

NEEDED RESEARCH

Needed EPM research includes defining the application development problem and proposing a development solution possibly within a three-pronged e-learning approach including:

1. *Creating a model for manufacturing training* based on online **collaboration technologies**, where a human master or coach is present to provide guidance and share experience with the apprentice
2. *Collecting resulting collaboration sessions* as a form of **content and knowledge management** to both tap into diminishing sources of experience and also be able to tune into the apprentice in order to provide best-fit online training sessions that are adaptable and reusable
3. *Building human capital* in the manufacturing industry by a process of early **distributed pre-training, assessment and recruiting** as a way to build relationships between the industries and the workforce of the future.

Among the obvious training benefits to be gained by this concerted approach is the fact that EPM is needed to help the manufacturing workforce stay in contact with the needs of the manufacturing industry, and through pre-training and industry apprenticeship, do more than inform about job opportunities. EPM is also needed to support our manufacturing workforce to stay competitive and/or be able to re-train for emerging advanced manufacturing jobs, as a migration path for other related (to the automotive industry) careers, such as in science, technology and engineering. The manufacturing workers of the future, through EPM, will be prompted to envision themselves in manufacturing careers, and will be provided with role models, access to manufacturing communities and a glimpse of the industry. It is by envisioning that true recruiting and aptitude can be tested, the closest thing to a shop-floor apprenticeship. Universities, post-secondary institutions, schools, libraries and community centers can all play a significant role in providing the same kind of access that we are making available to the educational community.

An industry overview of auto to makers and associated businesses employ one-seventh of U.S. workers (approaching two-fifths in some European countries) and represent one-tenth of America's consumer spending, (16). Of all the manufacturing industries in the world, it is the automotive industry that merits the most focus on education and training. The *2003 PriceWaterhouseCoopers Global Automotive Financial Review*, (17), of 13 vehicle manufacturers and 32 global suppliers, provides a comprehensive view of the size and complexity of the industry. The report shows that the automotive industry is a pillar of the world's global economy. The report very clearly points out (on page 39) that: "shortage of skilled resources is one of the toughest challenges that the companies face." And, it points out (also on page 39) that: "training and communications strategies are in place only in a quarter of the companies surveyed." By comparison, market projections foretell that in general, e-learning corporate expenditures will bypass traditional training in the next few years and will account for nearly half of the overall corporate training market, (18). At the turn of this Century, US corporations, in general, spent US$66 billion on job training. e-learning got just 3% or US $2 billion of that sum, but the online

learning market is expected to nearly double in size every year, reaching approximately US $11 billion by 2003 in the US alone. The Durable Manufacturing Industry, which includes machinery and transportation, depends on external sources of training and stands the most to gain from an e-learning solution for overall performance improvements, (19).

AN ARCHITECTURE FOR EPM

EPM is defined as a technology platform to support all aspects of personalized, sustained and longitudinally tractable online apprenticeship or coaching. EPM should support *just-in-time, just-enough, and just-for-you*, apprenticeship. Using data collection techniques, knowledge discovery, content management, educational constructs and collaboration technologies, EPM creates a new kind of platform for the apprenticeship and training environments. In order to accomplish these goals, EPM requires a modular architecture, as shown in Fig. 1, to accommodate components that can be tailored to assure maximum effectiveness in a distributed and collaborative e-learning environment, applicable as a public common resource, or at the corporate level for industry specific apprenticeship-training.

EPM COMPONENTS

1. **Integration Module Function**
   drive EPM portal
2. **Control Module**
   storage/management/analysis/security
3. **Coach Server Module Functions**
   learner/master/content/access model
4. **Client Module Functions**
   learner/master/content/access model
5. **Content Module Functions**
   - ✓ **Digital Library Component**
     move content to digital library
     XML indexing content scheme
     meta-language individualized content
   - ✓ **Data Warehouse Component**
     create a database of learner profiles & portfolios
     create a database of apprenticeship resources
   - ✓ **Data Mining Component**
     integrate with data mining for matching of content, apprenticeship and learners
     develop learner- targeted knowledge discovery application

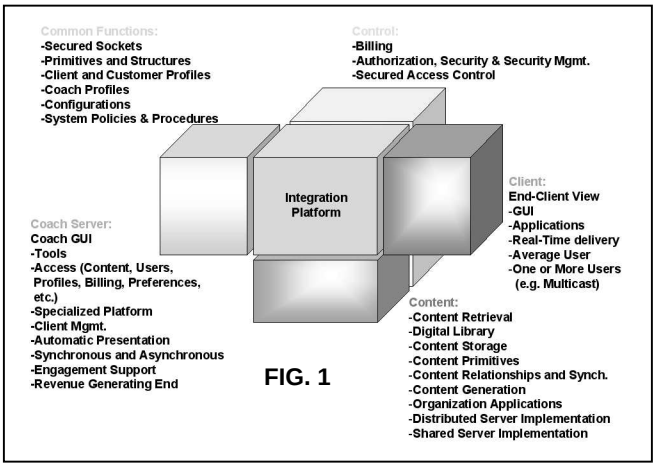

FIG. 1

EPM takes advantage of an architecture designed to support the development of a variety of education and training applications and it can therefore be generalized for use by other than the researched (automotive) industry. An important feature is its integration of the knowledge management and knowledge discovery components in the assessment process. The architecture is also meant to integrate with a state-of-the-art adaptive communications solution for access via the traditional wired (over the Internet or intranet) infrastructures, but that can also be used with *broadcast satellite* and *data broadcast transport mechanisms* such as cable, (20).

EPM FUNCTIONALITY

The functionality of the solution is based on constructs, structures and processes that can facilitate training through a series of models and representations of knowledge that bridge to social, cultural, ethnic, learning styles, past experiences and all relevant learner knowledge. The EPM architecture supports the kind of individualized training that is required to adapt to the concept of *learning and teaching styles*, as concurrent requirements in the apprenticeship-training model where a master and apprentice traditionally adapt to each other. This can be accomplished through technically sophisticated integrated collaboration sessions (envisioned in Fig. 2) suitable for information and knowledge management recording and analysis. An EPM data warehouse must be built over time to make the solution more powerful and flexible for adapting to the manufacturing industry at large and to specific related industries, such as industry parts suppliers.

EPM COLLABORATION SESSIONS

- ✓ Advanced knowledge management
- ✓ Individualized apprenticeships

just-in-time, just-enough, just-for-you

- ✓ Highly adaptive content management

any-where,any-time,any-content

- ✓ Reuse of content
- ✓ Adaptable telecommunications

synchronous and asynchronous

- ✓ Interactive access to rich media
- ✓ Two-way video streaming

two-way Communications
one-Way Content Playback

- ✓ Shared whiteboard
- ✓ Application sharing

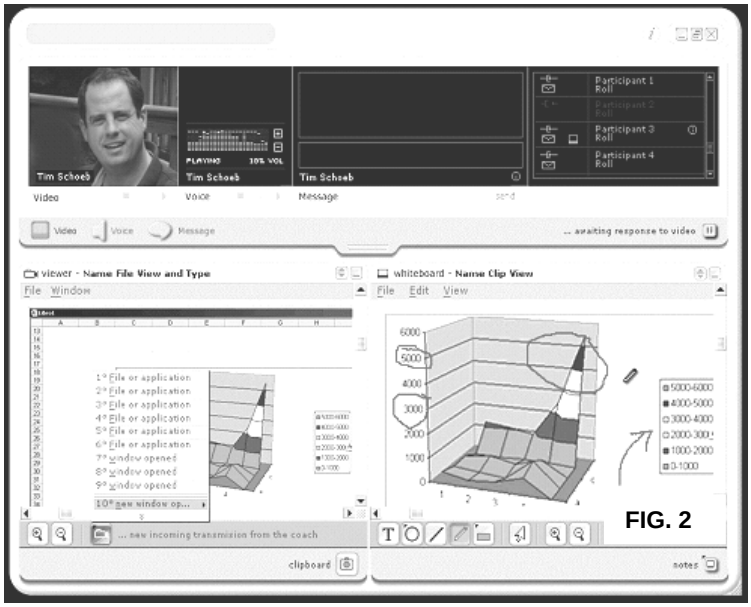

FIG. 2

Integrated Collaboration Platform

- ✓ Two-way video and audio
- ✓ Chat-space
- ✓ Shared whiteboard
- ✓ Application sharing
- ✓ Stored video support
- ✓ Courseware support
- ✓ Adaptable communications
- ✓ Private/group apprenticeship spaces

Advanced Content Management

- ✓ Relational databases
- ✓ IP asset
- ✓ Content media objects
- ✓ Interactive indexed content catalog

Knowledge Discovery

- ✓ Learners' and masters' profiles
- ✓ Portfolio record analysis
- ✓ Anticipated guidance

EPM PEDAGOGICAL FOUNDATIONS

EPM is designed to combine the features of both the *traditional and the cognitive apprenticeship models*. In the more traditional model the apprentice observes the expert

demonstrate the different parts of the task*. The expert makes the various parts of the task visible to the novice. The issue of observation is critical here. The expert is providing the conduct of the activity but also providing the learner with a task overview that serves as an advanced organizer for future observation sessions with the expert or with others where much of the learning occurs.* The apprentice observes the master who provides an overview of the task that serves as a benchmark for observations. The master shows the apprentice what to do until the learner is proficient to accomplish the task independently of the master. [http://www2.umassd.edu/SWPI/DesigninCS/DesignCS.html]

Cognitive apprenticeships are based on the social constructivist paradigm and reflect situated cognition theory. Realistic training situations are suitable for well-situated cognition processes based on knowledge organization techniques. [http://edtech.vt.edu/edtech/id/models/cog.html] Situated cognition creates a *negotiated learning process* between a master and the learner since they collaborate with one another to share understanding. Situated cognition promotes a natural learning style through activities, contexts and cultures, (21), which can be exploited as a form of knowledge organization and management.

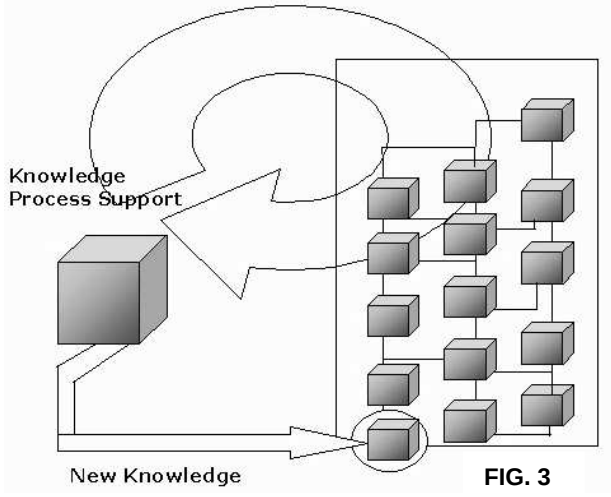

FIG. 3

A combination of these approaches through the use of *content management* and *collaboration technologies* can be implemented to manage the process in a systematic way, not unlike the assembly line concept that has so well served manufacturing. Through the deployment of advanced media, such as digital video clips of training material and two-way video, the learner can come as close to live apprenticeship environment as the master decides. Tasks can be simulated and live scenarios can be reached via two-way video. All of these options can be integrated in the collaboration environment with the addition of whiteboard sharing and application sharing for detailed training. Live chats and audio and video facilities can be made available to the master trainer. Data warehouse and data mining technologies can then used to support the knowledge management component. Unlike the traditional scenario, EPM will systematically construct apprenticeship units of knowledge, as shown in Fig.3, that include all the relevant media that is now lost, and the interactions, also lost, that take place during a given apprenticeship session. This material becomes a living-base of knowledge that can be mined for adapting to new situations and new learners. EPM builds on a well-understood integrated e-mentoring environment design with formal education mind, (22).

While it is important to incorporate what we now know about education and e-learning in the apprenticeship model, the training process in an apprenticeship is recognizably different in several important ways. We must consider these differences and use them as motivators for learning.

We take the following into consideration and incorporate *training bridges* in the e-learning design:

- The learner is an adult with social and economic motivators for learning.
- The learners represent varying social, cultural and economic backgrounds.
- The master is typically not trained in pedagogy, making the process of *adapting to the learner* a difficult consideration.
- The learner's current state of knowledge and academic achievement are less important than ability and attitude to perform the required tasks.
- The tasks may impose evaluating and reaching physical limits.

Organization of Knowledge and Learning Situations

Knowledge can be organized and applied differently by experts (masters) and novices (apprentices) [Ref. Cognition, 1990] – providing the fundamental educational basis for the apprenticeship model. Knowledge organization techniques can be used to identify training gaps based on continuous assessment and to structure clear training goals and limits. Based on a *negotiated learning process* that can be tracked for assessment and knowledge management purposes, EPM will be able to *construct knowledge maps* to three different categories of learning situations that range from inside to outside the portal. The goal is to have access through the portal to the combined knowledge background of the learner in order to make each learning experience become relevant to the integrated knowledge of the learner.

Three such situations for information gathering are suggested:

Apprenticeship	**Cooperative learning**	**Independent learning**
o Master intervention	o Group interactions	o Hands-on experience
o Shop-floor work time	o Courseware/training	o Time on tasks
o Software Simulations	o Other past record	o Other past record

These situations create tracking and assessment requirements that are difficult if not impossible to manage concurrently via conventional means in any learning scenario, and become even more difficult to manage and keep track of in the apprenticeship training model *as masters are not trained educators*. Empirical evidence collected from the Scotland experience, for example, will require time for analysis. There are other sources of data from e-learning based manufacturing training projects in existence around the world that can be collected to contrast findings. TV Ontario, for example, sponsors an automotive manufacturing portal that includes chats with experts, (23), but, a broad-based initiative at the policy level, such as that undertaken by the independent government of Scotland, are not outside of what may be required to address 21st Century understand the issues in manufacturing training. Independent and automatic tracking of the learners (apprentices) through the portal will provide learners in EPM with a sense of competence and accomplishment that currently can only come from employment opportunity. In this Model the sense of achievement and self-worth will become part of the training and preparation process leading to the acquisition of job skills and the ability to compete for employment opportunity. The process will become continuous, self-perpetuated and the same time

tractable, through the design architecture as illustrated in Fig.4, and functional specs, as illustrated in Fig.5.

Integrated Knowledge Management Component of the Architecture:

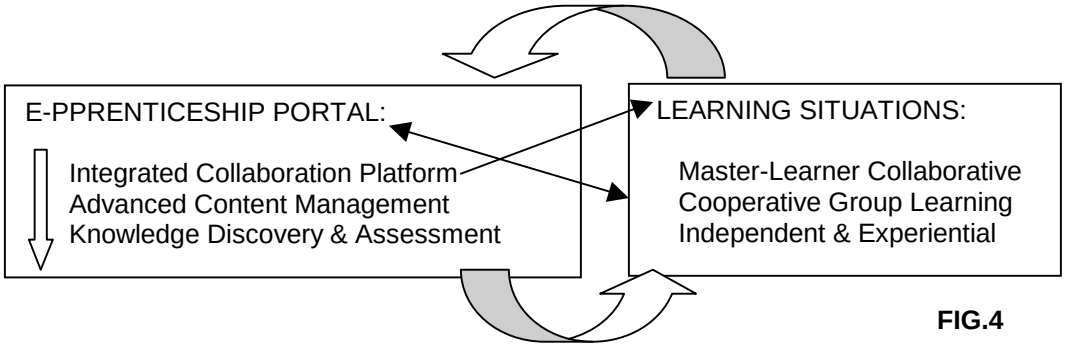

FIG.4

Integrated Functional Components of the Environment:

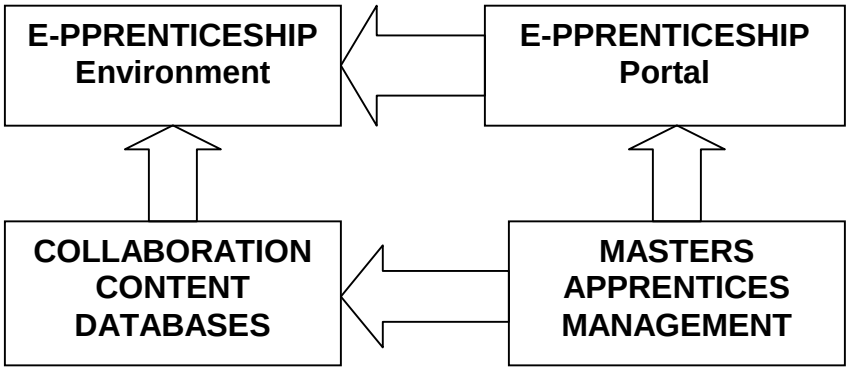

FIG. 5

IMPACT ON THE INDUSTRY AND WORKFORCE DEVELOPMENT

The EPM approach to manufacturing training for the 21st Century will make the difference between an advanced American manufacturing workforce of the future and unlimited outsourcing of our manufacturing industry. We hope to provide the tool that will undo the training, social and ethnic barriers that hold back the development of the American manufacturing workforce. EPM is the start of a solution that can promote understanding of the industry at large and can help eliminate the barriers that lack of effective training creates, impeding a larger segment of the population from considering careers in manufacturing. With the adoption of EPM as a concept and approach to (online) manufacturing training will come better understanding of the opportunities that the industry has to offer, and access to training and community building. In order to overcome the shortage of trained workers and the demise of the manufacturing industry as an American source of employment, we must include the manufacturing training community into the

larger Internet community and take advantage of all avenues for access that are constantly being enhanced - for this industry too.

Benefits:

- ✓ Conversion rate to full employment
- ✓ Income earned by during apprenticeship
- ✓ Apprentice level of completion
- ✓ Retention rates of employees
- ✓ Training costs of apprenticeship
- ✓ Return on employer apprenticeship investment
- ✓ Predictability of tracked performance outcomes
- ✓ Continuous improvement through knowledge discovery

Differentiators:

- ✓ INTERACTIVE highly adaptive approach
- ✓ INTEGRATED collaboration
- ✓ PRESERVATION of content/training development and human capital investment
- ✓ FOCUSED workforce assessment & recruiting
- ✓ VERSATILE application development platform

CONCLUDING REMARKS

We have learned through years of educational technology research that disparate approaches tend not to propel paradigm shifts in the culture. Faced with a political and socioeconomic crisis, America must consider the possibility of engaging in both a policy mandate and a paradigm shift that will turn the American manufacturing industry around. We not only have all the technologies needed to integrate a complete and holistic solution to serve the manufacturing industry, with its complex set of requirements and driving needs, but, we also have sufficient evidence to believe that such a solution would positively impact the industry. The IBM Corporation, for example, provides a similar internal management training solution that, while similar but not quite as advanced or dedicated to the apprenticeship scenario, was able to provide the corporation with a 2284% return on investment, (24). Clearly this is a strong indication that such solutions are the way of the future. Additional research is needed to explore the problem from the manufacturing training perspective and to prototype solutions. We have provided a new model for innovative manufacturing training, attempting to support with new technologies a vision that has been discussed at the Society of Manufacturing Engineers and at the National Association of Manufacturers under the theme of agile learning for agile manufacturing, (25). We hope to engender innovative ways to extend the benefits of online education to the communities and industries that in today's challenging global economy needs is the most, consistent with that theme. We hope to have made a contribution to the ongoing effort to improve our *manufacturing training industry* by outlining a model that addresses all the critical issues and the relevant e-learning technologies. The agility of the solution, however, continues to be only as powerful as the agility we apply to adoption of innovation.

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