Preliminary Results From a NSF-ATE Funded Distributed Hybrid Instructional Delivery Project

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Introduction

The National Center for Manufacturing Education (NCME) in partnership with the TAC/ABET accredited Quality Engineering Technology Department at Sinclair Community College received a two year National Science Foundation Advanced Technological Education (NSF-ATE) grant to develop and test a distributed-hybrid instructional delivery methodology. The primary outcome of the project grant is to evaluate the effectiveness of the delivery method as a means to increase the number of students in manufacturing related programs by providing institutions, companies, and students a way to work together both onsite and online in a cost-effective, practical way. The distributed hybrid instructional delivery method uses activity-based instructional materials for the face-to-face component, while online interactions allow the individual small groups (nodes) at the various sites function as part of a larger class, despite working at different locations and times. This paper reports preliminary results and provides examples of project deliverables.

This project extends Dan Coldeway's time and place framework for defining distance education systems, and is based on educational research including a key study at the University of Tennessee that concluded that twenty-six MBA students participating in a hybrid delivery system performed at a significantly higher level than students participating in just a resident program, $p < .01$ [1].

With this hybrid delivery system, the nodes are connected to each other and to subject matter experts by the use of course management software. The grant additionally supports a "community of practice" focusing on facilitating the application of the participant's skills to the solving of their workplace related problems. A final capstone experience within the certificate supports the design and implementation of a workplace based continuous improvement project.

A supportive objective is to adopt, develop, test, and evaluate the effectiveness of modified or new web-based learning objects in the support of the onsite instructional materials. The online instructional materials provide the supportive background material necessary to implement the previously NSF funded classroom instructional materials within the dispersed nodal environment.

Participants in the pilot testing of the distributed hybrid project can earn a short-term technical certificate in *Continuous Process Improvement* (CPI) from Sinclair Community College.

Background and Research

Sinclair Community College, through the Advanced Integrated Manufacturing (AIM) Center, received grant funds from the National Science Foundation (NSF) for the creation of a National Center of Excellence for Advanced Manufacturing Education (NCE/AME) currently known as the National Center for Manufacturing Education (NCME). A key deliverable of the Center is the development and implementation of a novel, activity-based, competency-based, contextual, industry-verified, modular curriculum in manufacturing engineering technology to be completed by June 2004. In order to accomplish the inquiry-based, hands-on learning goal, the Center's Project Development Team (PDT) proposed a new instructional architecture during the summer of 1995 [2]. The next three sections provides references to the supportive research and characterization of the instructional design architecture, instructional delivery modes, and creating a community of practice.

Module pedagogy

The project uses a module architecture developed by the NCME which reinforces our beliefs about effective learning and consists of four major elements, the "big picture," "authentic learning tasks," "closure and generalization," and the "transfer activity" [3]. The NCME model, as illustrated in figure one, is consistent with both Johassen and Rohrer-Murphy activity theory bases, and with vanMerriënboer's 4C/ID based instructional designs [4],[5]. The Jonassen and Rohrer-Murphy model shares many important characteristics with the NCME model. Both patterns can be applied to both the development of the instructional design, and the instruction itself. Both patterns work at all levels of the design: system, macro, micro. Both patterns develop a solution after context and problem definition. Both patterns focus on whole-to-part versus part-to-whole in the implementation process. Both patterns focus on the importance of sequence. VanMerriënboer's 4C/ID model characterizes two types of learning activities, part- and whole-task practice, which are equivalent, respectively, in the NCME model to the Authentic Learning Tasks (ALTs) and the transfer activities. Both the transfer activity and the whole-task-practice in the cited models stress the importance of providing the learner with an opportunity to integrate their skills learned in the smaller activities within a new context. Bransford (1999, 2000) advocates that all learning involves transfer from previous experiences and is enhanced by learning the concepts from the perspectives of different contexts [6], [7]. Table one provides additional supportive research for the elements within the instructional architecture.

The metaskills and communications skills are reinforced in each module by the application of core competencies that focus on how students think, how they communicate, how they interact with others, and how they use knowledge. Each learning activity provides closure and at the same time the facilitator guides the discussion back to the overall "big picture" in order to provide a broader view of the applicability of the skill set. The competencies supported by the module architecture are by their construction aimed at developing higher level thinking skills. The modules provide the activities for attaining and assessing the procedural knowledge and the

higher level thinking skills, but by original design intent did not provide the supporting materials necessary for achieving the sub competencies necessary for successful completion of the competency illustrated in figure one. The project is producing web based learning objects which provide instructional granules, such as text, video, audio, graphical organizers, completed examples, self-assessment exercises, and other assessment opportunities that will support the sub-competencies required for successfully completing the ALTs and transfer activities in the selected modules.

Table 1. Additional Supporting Research for the Module Architecture

Module Features	Supporting Research
• The "big picture" defines the contexts for all activities within the instructional unit. • An "authentic learning task" (ALTs) consists of a discrete event or experience through which students acquire one or more competencies. • The "transfer activity" allows the students to reinforce and extend competencies learned in the ALTs to a new authentic ill-structured problem. • The each learning task is designed to provide closure and generalization.	• Pask supports the need for a holistic, "whole-to-part" delivery of instructional materials [8]. • Herrington and Oliver support the creation of authentic learning environments and contexts with an authentic activity [9]. • VanMerriënboer supports the use of transfer activities, claims that the "appropriate design of whole-task practice is critical to reaching the goals...of problem solving and transfer of the non-recurrent aspect of complex cognitive skills as an overall learning outcome" [5]. • Lynch cites the need for learners to apply their problem solving skills "to the real world environment in which they live/work"[10]. • Mayer hypothesizes that asking learners to solve ill-structured problems reinforces the need for developing metaskills; that is, strategies for how to use their knowledge in problem solving[11].

Ertmer and Newby, supported by Spiro, etc., suggest that the requirements of the task to be learned define the instructional approach. For declarative and structural knowledge typically found in supportive sub competencies, a low to medium level of cognitive processing is necessary. A low degree of cognitive processing includes knowing the facts or steps, knowing what, and typically uses the behaviorist approach to learning, for example the triad of practice/reinforcement/feedback for learning and memory instruction. Typically in medium levels of cognitive processing, knowing why, "schematic organization, analogical reasoning and algorithmic problem solving" methods are appropriate. Examples of activities that require higher level thinking skills, include case problems, simulations, situated learning, cognitive apprenticeships, and other constructivist approaches to instruction focus on knowing how, and knowing knowing [12], [13]. Table two provides a summary table that indicates the relationship between the cognitive level of knowledge and suggested instructional strategies. This approach to selecting the instructional strategy based on the knowledge taxonomy is the approach implemented by the team.

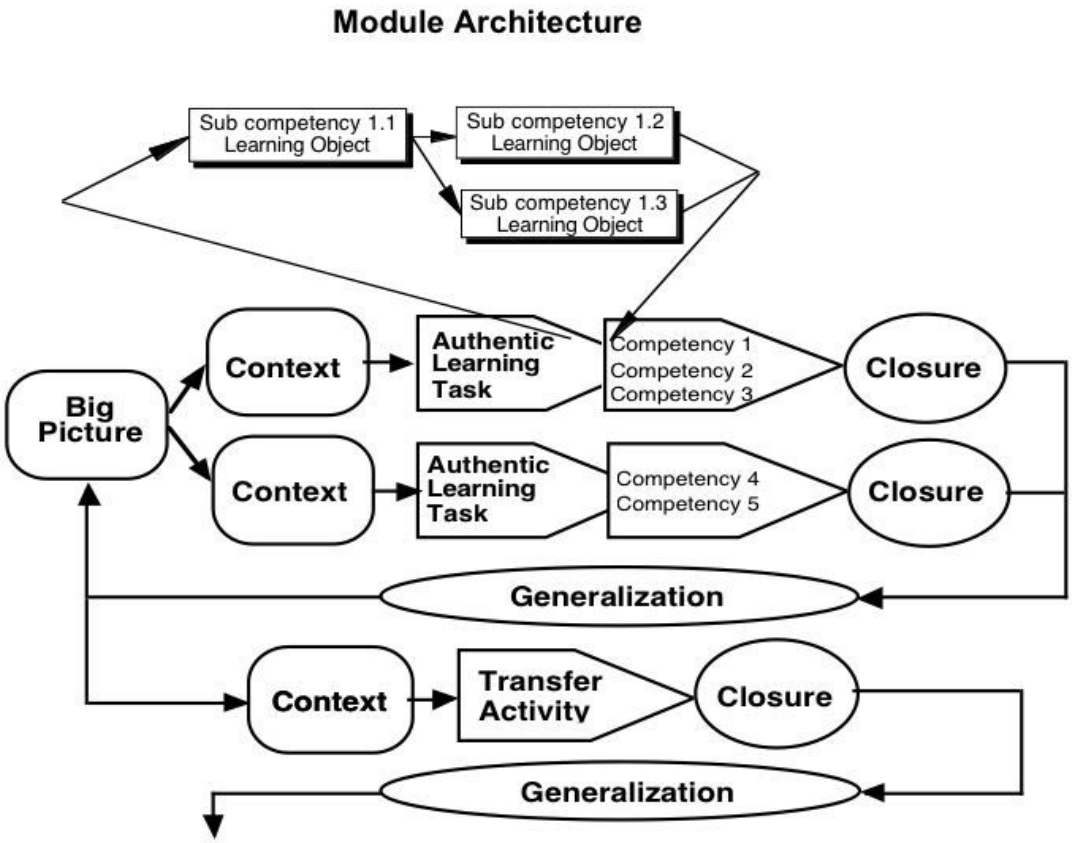

Figure 1. NCME Module Architecture

Table 2. Relationship between Learning Taxonomy and Instructional Strategies

Bloom[14]	Anderson/Jonassen [15],[16]	Reigeluth [17]	Suggested Instructional Strategies
Knowledge	Declarative knowledge	Memorizing information	• Direct Instruction** • Inductive Thinking** • Gagne's Nine Stages of Instruction
Comprehension	Structural knowledge	Understanding relationships	
Application	Procedural knowledge	Applying skills	• Simulation Models • Experiential Learning* • Inquiry Learning* • Problem Based Learning*
Analysis Synthesis Evaluation	Metacognitive knowledge	Applying generic skills	

*Typical approaches used in the development of the ALTs and transfer activities.
**Approaches in use for the new instructional materials to be developed in this project.

The authentic learning tasks and transfer activities developed in the instructional materials within the modules focused on learning strategies supportive of the higher order thinking skills and typically applied experiential, inquiry, and problem based learning. The use of direct instruction and inductive thinking strategies is in support of the learning objects which are designed to support the ALTs and transfer activities. M. David Merrill's "First Principles of

Instruction" provide the underlying criteria for developing new or evaluating existing learning objects [18]. Table three provides a rubric, based on the First Principles, used for assessing the completeness of the learning objects. The next section, following table three, reviews literature related to the instructional delivery mode and outlines the chosen characteristics of mode currently being tested.

Table 3. Learning Object Assessment Rubric

Principle	Assessment Criteria
Problem	• Does the LO present a problem in the context of the real world? • Does the content show the learners the task or problem that they will be able to solve as a result of completing the LO? • Is the learner engaged at the problem or task level not just the operation or action level? • Does the content, if appropriate, support a progression of problems rather than a single problem
Activation	• Does the LO attempt to activate relevant prior knowledge or experience? • Does the LO direct the student to recite, relate, describe, or apply knowledge from relevant past experience that can be used as a foundation for the new knowledge? • Does the LO provide relevant experience that can be used as a fountain for the new knowledge? • Does the LO provide a diagnostic pretest at the start of each unit? • Does the LO activate a mental model?
Demonstration	• Does the LO demonstrate (show examples) of what is to be learned rather than merely tell information about what is learned? • Are learner guidance techniques used? • Is the media relevant to the content and is used to enhance learning?
Application	• Does the learner have an opportunity to practice and apply their newly acquired knowledge or skill? • Are the application and the posttest consistent with the stated or implied objectives? • Does the LO require the learner to use new knowledge or skill to solve a varied sequence of problems and do learners receive corrective feedback on their performance? • Are learners able to access context help or guidance when having difficulty with the materials?
Integration	• Does the LO provide techniques that encourage the learner to integrate (transfer) the new knowledge or skill? • Does the LO provide an opportunity for the learner to publicly demonstrate their new knowledge or skill? • Does the LO provide an opportunity for the learner to reflect-on, discuss, and defend his or her new knowledge or skill? • Does the LO provide an opportunity for the learner to create, invent, or explore new and personal ways to use his or her new knowledge or skill?

Instructional delivery modes

The possible delivery continuum of solutions runs from fully temporally and geographically diverse distance education, taught at multiple institutions, to traditional face-to-face classroom/ laboratory delivery. In order to select the "best" solution, the project development team proposed six possible delivery solutions for evaluation based on specified criteria found in table four. A mandatory criterion is the ability to meet TAC/ABET accreditation requirements. The team tried to gain specific answers to all of the listed criteria for each of the delivery modes. It was determined that the numbers were not available, because of the uniqueness of the proposed delivery method and thus became important evaluation measures within the proposed grant.

Table 4. Possible Instructional Delivery Solutions and Criteria for Selection

Possible Delivery Solutions	Criteria for Selection
Option 1: Face-to-face instruction, with adoption of program based on full institutional commitment. Option 2: Hybrid face-to-face and web based distance education, based on single site delivery. Option 3: Distributed hybrid face-to-face and web based distance education, single institution offers. Option 4: Distributed hybrid face-to-face and web based distance education, multiple institutions offer. Option 5: Pure web based distance education, single institution. Option 6: Pure web based distance education, multiple institutions.	• Will the proposed method meet accreditation requirements? (TAC/ABET) - *Mandatory Requirement* • Does the delivery method support the most effective instructional strategies? • What is the level and quality of the interactivity and responses? • What is the delivery units' instructional retention rate? • Does the method satisfy student and employer needs? • What is the difficulty of hiring qualified facilitators? Faculty? • What portion of the instructional unit must be delivered at an institution versus a remote site (including ones home or workplace)? • What portion of the instructional time is fixed? • What is the complexity of the delivery technology? • What is the overall ease of adoption of the materials? • What is the dollar cost to the participant per Carnegie unit? • What is the fixed dollar cost to the institution per Carnegie unit based on a five-year depreciation cycle?

The use of hybrid instruction (Option 2) versus pure e-learning (Option 5) has exploded across college campuses as documented by Young [19]. Additionally, Grobler advocates the use of blended instruction (Option 2) that includes face-to-face, with e-learning as the only way to guarantee effective student learning [20]. National Science Foundation DUE-Advanced Technology Education Awards over the past seven years have supported research efforts studying the use of distance education and various media to deliver or to support student learning in technology or supportive courses. Table five categorizes these grants into two categorizes (1)

creating web-based resource centers, (2) and developing and delivering web based distance education courses (Options 5 and 6).

While the studies, cited in table five, address distance education in science, mathematics, engineering, and technology only the Wisconsin-online group is producing manufacturing engineering technology learning objects and none focus on the distributed-hybrid (DH) delivery method.

Table 5. Recent DUE Distance Learning Grants

Grant Category	DUE Grants
Creating web-based resource centers	• Chang's (1999) creation of a web based resource center[21]. • Washington State's project investigating online learning environment[22]. • Owens and Pelton's (1995) project to create a distance learning program for undergraduate engineering adult learners in industry[23]. • Bringsjord, S.C. and R.W. Noel's "Super-Teaching" project[24].
Developing and delivering web based distance education courses and investigating potential pedagogues on the web	• Kurose's (1999) efforts to create and deliver a fully web based computer science degree[25]. • South Dakota project to deliver electronics education to upper level high school students[26]. • Maui Community College's efforts to deliver an electronics curriculum using teleclasses and simulated multi-media laboratory experiments[27]. • MATEC project using web based simulations to deliver sixteen instrumentation and control[28]. • Wisconsin-On Line learning objects project. This project to date has developed over 1000 learning objects related to mathematics, science, English, and technology[29].

No research studies had been published related to the proposed delivery mode until the faculty at the University of Tennessee recently concluded that twenty-six MBA students participating in a hybrid delivery system performed at a significantly higher level than students participating in just a resident program, $p < .01$ [1]. The hybrid delivery system (Option 2) consists of resident instruction and the use of the World Wide Web and/or synchronous cyber classes. Another highly successful MBA hybrid program is at Ohio University[30]. A successful example of the use of a distributed-hybrid delivery of courses occurs at the doctoral level at Purdue's School of Education[31]. Given the level of student interaction, and cost considerations, the project team selected that an appropriate distance delivery modality for the NCME modules could a DH model (Options 3 or 4). Another key deliverable of this involves the development of a student lead community of practice. The next section discusses the importance of providing opportunities for learners to engage in a supportive community of practice.

Community of practice

Dewey and Vygotsky proposed a social-constructivist view that "the theory of individual learning that pervades schools is flawed" therefore, there exists a "need for a supporting

community to provide the framework for individuals to construct their own knowledge" [32]. Tu and Corry (2002) classified possible communities as, communities of interest, communities of purpose, communities of passion, and communities of practice. "Communities of practice focus on a common set of activities and are composed of people who share common or related professional responsibilities and activities that can often catalyze breakthrough thinking" [33]. Communities of practice can also be distinguished by their emphasis on both vertical learning (i.e. novice - expert) and horizontal learning (i.e. novice - novice), and on both individual and community learning. The community of practice first proposed by Lave and Wenger was based on a social theory of learning, which included the key elements of the theories of social practice and of identities [34], [35]. Legitimate participation defines ways of belonging to a community of practice, these ways can include community membership, both locally and within related communities, and the members trajectory: peripheral, inbound, insider, outbound or boundary.

The following list summarizes the key characteristics of the distributed hybrid instructional delivery method.

- Uses the previously developed instructional modules to provide face-to-face small group competency-based activities led by a facilitator who can be classified as a competent practitioner.
- These activities support the acquisition of procedural knowledge, higher level thinking skills, oral presentations, and team building processes.
- Students form natural study groups.
- The end of the module transfer activities can be customized to solve a specific company macro-context or the instructor can use the currently designed macro-context "Robotic Grippers Inc."
- Each group can meet at different times and different places.
- Declarative and structural knowledge necessary to support the competency-based activities are provided over the web in the form of learning objects, graphic organizers, worked examples, self-testing, and examinations.
- All students can access the instructional materials at different times and places.
- All students will have opportunities to connect with subject matter experts outside of the course structure using "virtual conferences" and discussion forums.
- Students can continue their contact with other students using discussion forums and e-mail.
- The program can provide opportunities at any industry or college site that has access to the necessary equipment.
- The distributed-hybrid approach offers the possibility of an accredited Manufacturing Engineering Technology distance education program. Currently, nationwide, there are only 14 TAC/ABET accredited Manufacturing Engineering Technology Associate degree programs thus limiting underrepresented student access.

The next major section discusses the project goals and objectives and examples of their current status in support of our summary characteristics.

Project Goals, Objectives, and Deliverables

The goal of this project is to develop, test, and evaluate the effectiveness of new web-based

primary instructional materials, leading to a certificate in *Continuous Process Improvement* (CPI), that utilizes a unique distributed-hybrid delivery model. The project objectives are to:

1. Supplement fifteen existing NCME face-to-face instructional modules (delivered within eight college classes) with web-based declarative and structural supporting materials, within a reusable learning object format, suitable for a distributed-hybrid method of delivery.
2. Pilot test the materials and delivery method at a total of two or more industry and college sites with an average of four or more students per site per term;
3. Develop a web-based virtual "community of practice" over the length of the program that includes subject matter experts, participating students, and module instructors for the purpose of creating self-sustaining, student-led environments for sharing and growth;
4. Test the effectiveness by comparing student performance and retention in at least four modules; student, faculty, college, and industry satisfaction; and institutional and industry return on investment when compared to face-to-face or pure web based instruction;
5. Research and create a dissemination plan that addresses adoption barriers identified in the project.

Figure two illustrates the content titles and organization of the instructional units within the Continuous Process Improvement certificate in support of objective one.

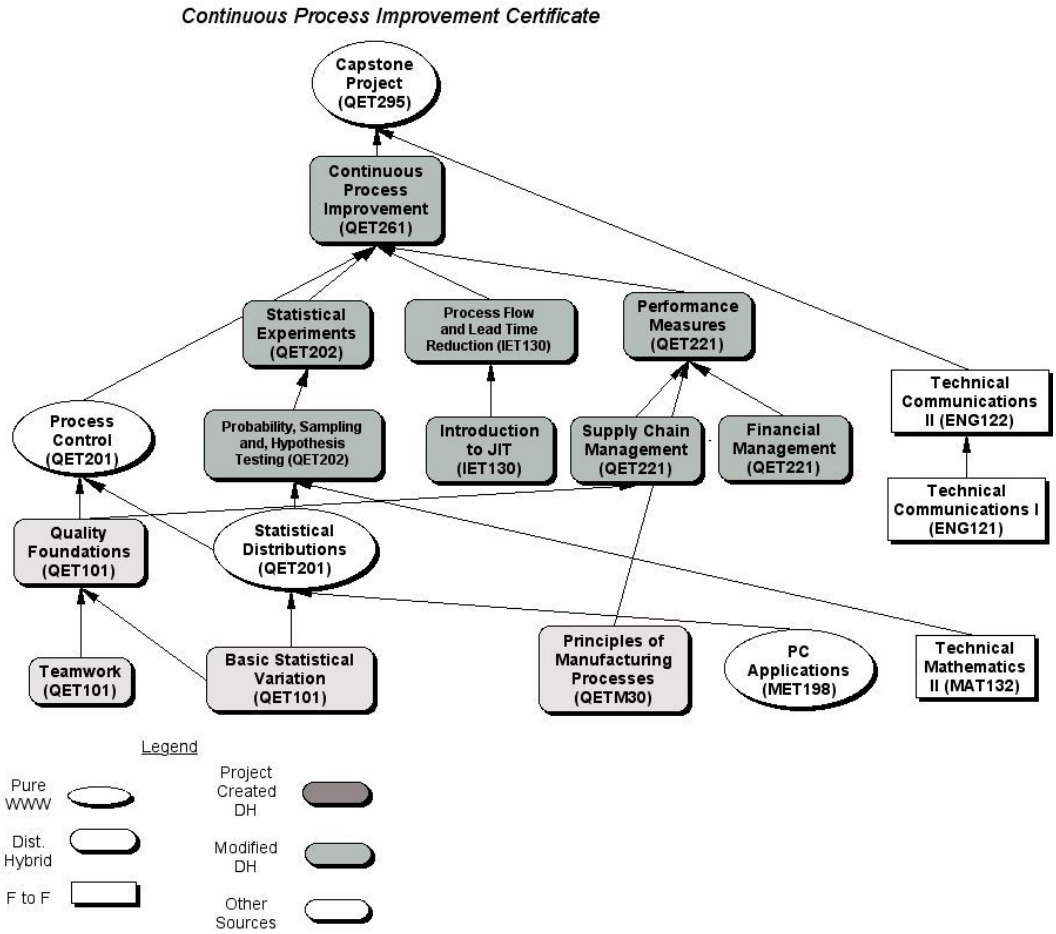

Figure 2. Modules, with Prerequisites, for the Certificate in Continuous Process Improvement

The DH development team typically uses subject matter experts that were involved in the writing of the original module to develop materials and learning objects to support the activities within the modules. The DH instructional designer reviews and organizes the materials per a team developed worksheet. An example web development worksheet for ALT#3 in the *Teamwork* Module is illustrated in figure three.

Learning Event	**Location of Content**	**Learning Strategy Teamwork ALT#3: The Meeting**			**Respon-sibility**
		Individual	**Face-to-Face**	**Web Group**	**P, F, I**
Overview	PJ p29 FG p35	Read module material			P, F
Materials and Equipment	FG p35		Gather materials for activity		F
Safety and Disposal	PJ p29 FG p35	Read module material			P, F
Preparation	FG p35				F
Pre-Activity (learning objects)	FG p35-36	-Read Information Sheet: Surviving a Nuclear Attack -Read Information Sheet: Team Member Meeting Roles -Learning Object #1 (be sure to do post-test): http://pigseye.kennesaw.edu/~tcarnes/conductingameeting.htm -Learning Object #2 (be sure to do the exercise): http://www.prenhall.com/pauline/Html/Ex1.html			P, F
Activity	PJ p36 FG p43				P, F
Assignment	PJ p36 FG p43			Post results and summary on discussion board	P, F
Assessment	PJ p37 FG p44	Read rubric for assessment criteria			P, I

Figure 3. Example Distributed Hybrid Instructional Design Worksheet

The development and pilot testing sequence of the developed web based materials and assessment instruments, that support the declarative and structural knowledge requirements necessary to support the face-to-face activities is outlined in table six. The modules highlighted in bold represent testing of the DH materials.

The module activities and web supplements, in the form of learning objects, developed under this grant provide sufficient skills to qualify for the awarding of a certificate in *Continuous Process Improvement*, a subset of an overall associate degree. Based on job opportunities and SME documented industry needs students that finish the CPI certificate will have demonstrated achievement of a marketable set of manufacturing and quality management skills.

Table 6. Distributed-Hybrid Pilot Testing Sequence and Credit Hours by Academic Quarter

Winter 2004 (8 credit hrs.)	Spring 2004 (9 credit hrs.)	Summer 2004 (8 credit hrs.)
• *Teamwork* (QET 101) • *Basic Statistical Variation* (QET 101) • *Quality Foundations* (QET 101) • PC Applications (MET 198 - 2 cr. hrs.) or equivalent • Technical Communications I (ENG 131 - 3 cr. hrs.) or equivalent	• *Statistical Distributions* (QET 201) • *Process Control* (QET 201) • Technical Math. II (MAT 132 - 5 cr. hrs.) or equivalent	• *Introduction to JIT* (IET 130) • *Process Flow and Lead Time Reduction* (IET 130) • Technical Communications II (ENG 132 - 3 cr. hrs.) or equivalent.
Fall 2004 (9 credit hrs.)*	**Winter 2005 (3 credit hrs.)**	**Spring 2005 (3 credit hrs.)**
• *Probability, Sampling and Hypothesis Testing* (QET 202) • *Statistical Experiments* (QET 202) • *Financial Management* (QET 221) • *Performance Measures* (QET 221) • *Supply Chain Management* (QET 221) • *Principles of Mfg. Processes* (QET M30)	• *Continuous Process Improvement* (QET 261)	• Capstone (QET 295)

*Community of Practice and Second cohort group starts
QET 101 offered Fall, Winter, Spring terms as DH/ regular class, QET 201 offered Summer, Fall as a web only, Winter, Spring as DH/ regular class, IET 130 offered Spring as a DH, QET 202 offered Fall only as a DH, QET 221 offered Fall only as a DH, QET M30 offered Fall only as a DH, QET 261 offered Winter only as a DH, QET 295 offered Spring as a web only class, MET 198 offered as a web only or as a regular class.

Project objective three is to develop a web-based virtual "community of practice" over the length of the program that includes subject matter experts, participating students, module instructors, and facilitators for the purpose of creating self-sustaining, student-led environments

for sharing and growth. In order to achieve this objective the model class creates a network of nodes and participants. Each node consists of at least four students and a facilitator that meet face-to-face to complete the instructional activities developed within each module, as part of the web based modular class. The supporting structure includes the multiple networks of nodes, a web/course management system that supports the delivery of the necessary declarative and structural knowledge, and the technology that supports horizontal and vertical communications. As a deliverable from this project, Principal Investigators Gilah Pomeranz and Paul Giguere have developed web based resources available to support the two different facilitation roles, face-to-face and web.

The use of the face-to face instructional modules developed by the NCME and the use of a distributed-hybrid (DH) instructional delivery method provide the basis for meeting Wenger's instructional design elements[35]. The face-to-face facilitation of the activity-based materials at the nodes satisfies the requirement of places of engagement. The activity-based materials based on Kolb's learning cycle providing materials and experiences with which to build their own image of the world[36]. The third element, the use of a transfer activities will allow the learners to apply what they have learned to a new context, such as their workplaces, and provides a mechanism for the learner to have an effect on the world. The use of a DH modality provides the supportive structure for student learning at multiple levels including; face-to-face facilitation at each node of four to six students, node-to-node and learner-to-expert interactions occur using a discussion forum. The proposed modality should include the use of virtual conferences and companion discussion forums, to provide greater support for interactions between experts and the overall community. The desire to have a student led, self-sustaining community is more problematic, and will require creating a community, through training and facilitation, with the skills to transition from being faculty led to being student led. A community of practice requires both horizontal and vertical two-way communications between students, facilitators, the instructor, outside subject matter experts, and inside the "company" subject matter experts. The interactions include both face-to-face and by electronic means, including instant messenger, telephone, e-mail, chat, discussion forums, and virtual conferences.

The last two objectives the evaluation of the materials and the creation of our dissemination plan are key to the ultimate adoption of this model. The evaluation of the DH methodology is led by the Social Science Research and Evaluation Corporation (SSRE). The pilot tested of the evaluation instruments occurred during the winter term of 2004. The evaluation effort is aimed at answering the questions posed in table four. The PI team is developing a dissemination plan based on Rogers' principles as outline in *Diffusion of Innovations*[37].

Urgency for Solving the Problem

The Society of Manufacturing Engineers has documented the need for qualified technicians and manufacturing practitioners, at the same time the number of TAC/ABET accredited programs has dropped from eighteen to fourteen. Given the current economic conditions it is safe to predict that the number of manufacturing and manufacturing related programs will continue to decline, reducing student access to these programs, unless some new intervention is proposed. Pure web instruction can not always be used to deliver laboratory content, current solutions require either

moving the laboratories to the students or moving the students for extended time to the laboratories. These choices are costly logistic nightmares or prohibitive in cost and time for the typical two-year college student. The DH delivery methodology provides a cost effective alternative with the *CPI Certificate* providing a coherent body of knowledge to test the delivery methodology.

Summary

The impact of the documented project is potentially national in scope, and could change the way college level educational content is delivered by adding another point on the continuum between pure face-to-face and pure web-based. A concept review by Drs. Simonson from Nova Southeastern University, and Branch from the University of Georgia attested to the uniqueness and value of the research on the distributed-hybrid delivery method. This approach ends the isolation of the distance education student by providing a combination of group face-to-face and individual asynchronous learning opportunities. The effectiveness of the delivery system is accomplished by providing the students with high quality instructional materials and activities.

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