Journal of
INDUSTRIAL TECHNOLOGY

Volume 20, Number 2 - February 2004 to April 2004

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Peer-Refereed Article

KEYWORD SEARCH

Curriculum
Manufacturing
Research
Teaching Methods

The Official Electronic Publication of the National Association of Industrial Technology • www.nait.org

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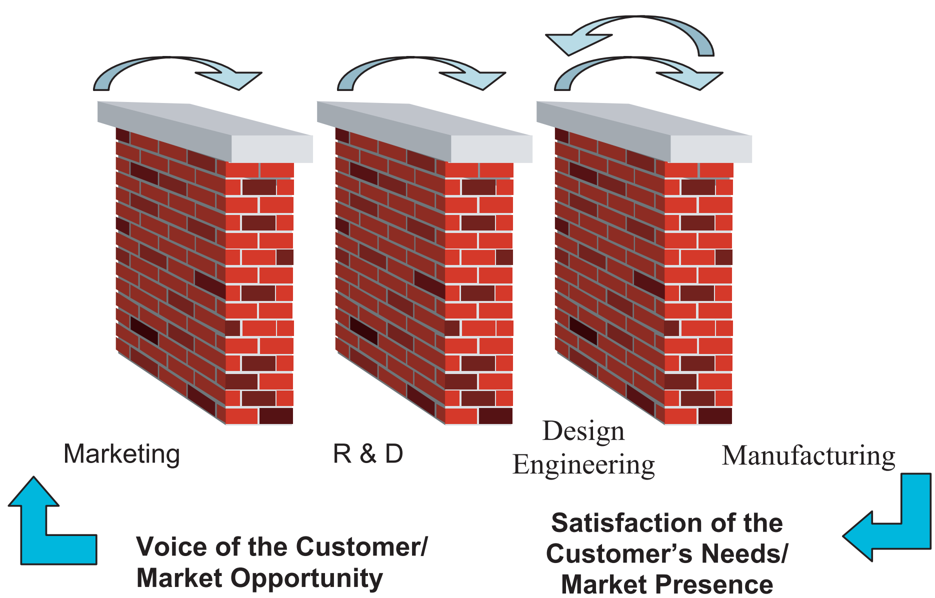
Testing a New Approach for Learning Teamwork Knowledge and Skills in Technical Education

By Dr. Joseph C. Chen and Dr. Jacob Chen

Teamwork skills have become an important part of the workforce in manufacturing- related industry (Hertz, 2003, & Mookazis, 2000). Traditionally, product design has progressed from Marketing to Research and Development (R&D), to Engineering, and finally to Manufacturing. The professionals in manufacturing appraised the designs based on their manufacturability and then sent them back to Engineering for modification. Engineering then passed them back to Manufacturing for assessment, and the cycle continued (see Figure 1). Many industries are still using this traditional engineering design process; however, this sequential product design path is very time consuming and inefficient when problems are encountered.

Unlike its traditional and problematic counterpart, the concurrent engineering design uses team approaches to bring the departments together, including the input elements, processes, and output elements necessary for production (Bertoline & Wiebe, 2003). In this instance, professionals from each department meet in an attempt to discuss, solve and prevent problems from arising in future production (see figure 2). This team-oriented design process involves Design for Manufacturability, or DFM. Anderson (2001) indicates that DFM is effective to deal with the problems of product quality, cost, and time to market. Consequently, DFM provides "guidelines to aid the designer in enhancing the manufacturability" (Bralla, 1999).

Figure 1. Traditional, sequential product development ("Throw it over the wall").



With the benefits of using concurrent design processes that emphasize teamwork in mind, more and more industries are using concurrent engineering design processes.

In a survey about improving manufacturing and design capabilities, 66 senior managers from 33 manufacturing companies were asked to rank a list of 56 different "best practices" in order of their importance in the manufacturing workforce. Teamwork was ranked as both the number-one skill that manufacturing employers look for and that entry-level employees lack (Przirembel, 1995).

The gap between what American industry wants and what new graduates are able to provide is worth the attention of technical educators. The current American education system is one of competition and individualism, while American industry is moving away from "rugged individualism" and toward a more collaborative, team-oriented approach to business (Anderson, 1998). Therefore, technical education must follow long-term industrial trends to help students gain awareness of industry expectations and proper teamwork skills.

Some technical educators are aware of the need for teamwork skills in American industry, but teamwork training is generally limited to small group projects. The rationale behind this usually comes from cooperative learning as general. Cooperative learning is the instructional use of small groups so that students will learn to work together to help themselves and each other learn. The completed assignment is a result of the whole group's efforts. However, placing students in groups and telling them to work together does not result in cooperation. Without proper teamwork training, students may still lack several people-oriented values such as listening, presenting one's own ideas, responding constructively to others, providing support, recognizing the interests and achievements of others, building team charters, and managing conflict, among others (Anderson, 1998). In addition, for students who are seeking a competitive edge in the manufacturing industry, this is not adequate. Students need more than just general cooperative learning knowledge and skills. They will be better prepared if they are introduced to the teamwork knowledge and skills that are tailored for the needs of their future manufacturing-specific careers.

In an effort to begin closing the gap between what employees provide and what employers want, a National Science Foundation (NSF) sponsored project was proposed to develop a curriculum in an introductory manufacturing design class with the intention of teaching community college students basic teamwork skills and knowledge necessary for future employment. The proposed curriculum and the pilot testing of the curriculum, (both the procedure and the results), are described in the remainder of this paper.

The New Method of Teaching Teamwork in Technical Education

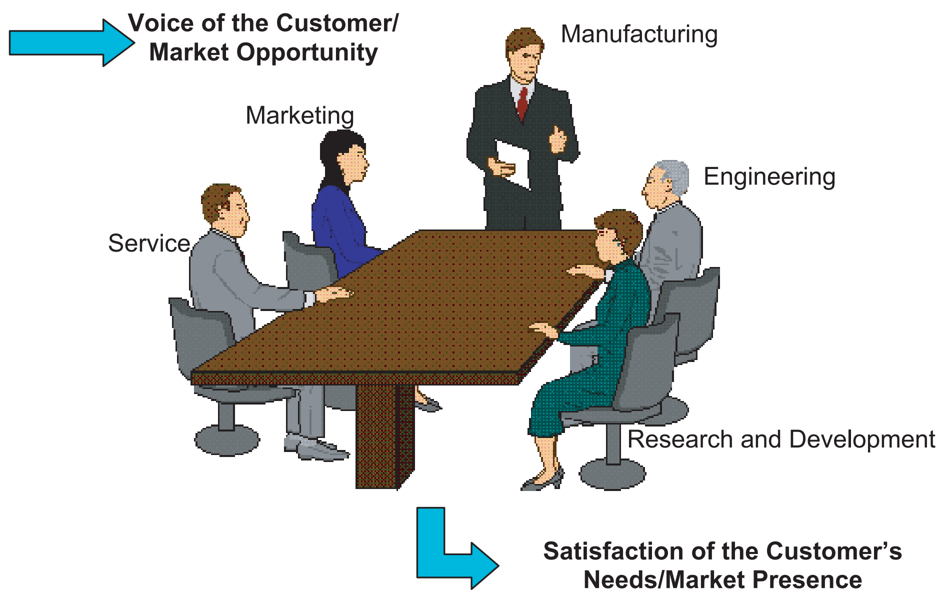
The Curriculum Background

This curriculum development was part of a three-year Advanced Technical Education (ATE) project granted by the NSF. This project considered the industry's demands and the effects of those demands on future employees in order to improve teaching methods and curricula in community college manufacturing education programs. According to Przirembel's survey (1995), design for manufacturability (DFM), computer-aided design (CAD), teamwork and communication were in high demand—they ranked among the top five desirable skills in the industry. Based on the industry's needs, elements of DFM, CAD, and teamwork (including communication) were combined into one effective curriculum. Teamwork knowledge and skills were therefore taught within the context of DFM and CAD. The purpose of this study was to investigate how a two-fold teamwork curriculum that combines knowledge with practice and operates within the context of DFM and CAD instruction affected and enhanced student teamwork skills.

Contents of teamwork knowledge and skills included in the curriculum

The teamwork knowledge and skills included in the curriculum were developed according to the suggestions from the industrial representatives on the project advisory board and the

Figure 2. Concurrent product design involves all members.



researchers' teaching experiences. They include the following areas:

- Essential team skills (including building team charters, writing meeting agendas, recording meeting minutes, etc.)
- Six team decision-making skills (brainstorming, nominal group technique, Delphi technique, consensus card method, paired-choice matrix, and criteria rating technique)
- Introduction of different types of work teams with an emphasis on self-directed temporary project work teams
- Becoming an effective team member
- Project management (involving the development of Gantt charts and flow charts)
- Communication skills, both verbal and non-verbal
- Solving team problems and conflicts

Ways of delivering teamwork knowledge and skills

The curriculum was further divided into four modules, each of which takes about four weeks of instruction. Each module was composed of all three subject areas in the curriculum: teamwork, parametric solid modeling, and design for manufacturability. The suggested total instruction hours (including lecturing and team activities) on the teamwork were 12.5 hours for the whole curriculum. Teamwork knowledge was delivered through PowerPoint presentations and class discussion. Each lesson came with in-class team activities that provide the students with hands-on experience. An instructor guide, including preview sheets, PowerPoint slides, PowerPoint presentation scripts, information sheets, and assignment sheets (in-class team activities), was developed to aid the educators in presenting and teaching the teamwork curriculum.

Pilot Testing the Curriculum

The instruction curriculum was designed and developed through the cooperative efforts of three institutions: two community colleges in Iowa and South Dakota, respectively, and Iowa State University. The resulting curriculum was pilot tested at Iowa Western Community College in the spring semester of 2002.

Surveys and Class Taping for Curriculum Modification

The curriculum developers had several questions in mind from the pilot test, including the following:

- Is the teaching sequence logical to both the students and the instructors?
- Is the time allotment appropriate?
- Are the contents interesting to students?
- Do the PowerPoint slides and PowerPoint presentation scripts make sense?
- Are the assignments reasonable?

To find out the answers, the developers designed two surveys, one for the instructor and one for the students, to be completed following the lessons. At the end of each module, the surveys were returned to the project staff at ISU. These surveys were summarized, and a meeting was then held with the instructor to make the appropriate modifications. In the lesson survey for the instructor, he was asked to rate each lesson objective and comment on whether or not that lesson objective could be accomplished through the curriculum materials. An example of an instructor lesson survey is shown in Table 1. In the lesson survey for students, they were asked to rate each lesson objective and comment on if that lesson objective can be accomplished through the curriculum materials and the instructor's instruction and other classroom activities. An example of a student lesson survey is shown in Table 2.

The instructor was also asked to videotape each class to monitor progress. The resulting tape, which was viewed by the project staff, was used to observe the interaction between the students and the instructor, to learn if the content of each lesson was smoothly designed and easy to teach,

Table 1. An example of an instructor lesson survey

Lesson Objective	Rating (1-5)	Comments
1. Explain why teamwork skills are essential to manufacturing organizations.	5	Very clear.
2. Define a team charter and know what should be included in a team charter.	4	Could be more specific.
3. Explain what the facilitator of a team should do.	4	Some examples?
4. Explain what the recorder of a team should do.	5	Very clear.
5. Write the meeting agenda for a simple task.	5	Very clear.
6. Identify the action items as the most important part in meeting minutes.	4	A little challenging for students.

Table 2. An example of a student survey

Lesson Objective	Rating (1-5)	Stu#1	Stu#2	Stu#3	Stu#4	Stu#5
1. Explain why teamwork skills are essential to manufacturing organizations.	5	4	4	4	4	4
2. Define a team charter and know what should be included in a team charter.	5	3	4	4	5	3
3. Explain what the facilitator of a team should do.	5	4	3	5	5	3
4. Explain what the recorder of a team should do.	5	5	4	5	4	3
5. Write the meeting agenda for a simple task.	5	5	4	5	4	4
6. Identify the action items as the most important part in meeting minutes.	5	4	4	5	5	3
Comments: 1. It really explained the importance of teamwork. Told how different type of people that work in manufacturing can work together. 2. Learning good teamwork skills. 3. Teamwork is very important to all designers. It helps production assembly faster. 4. It outlined what teamwork is and didn't give too much useless information.						

and to solve problems and make improvements for each lesson. The tapes were transcribed and analyzed at ISU. An example of a transcribed lesson is shown below:

M1T2

Script – 20 minutes

<u>Slide 1</u> – Added: In some teams, one or two members try to dominate and the group goes only in one direction. If every team member gives their ideas, the team can make decisions based on many different, diverse perspectives.

Info sheet 1 – Read the basic rules and explained why they are important.

1. *Getting more ideas on the table is the goal.*
2. *This wastes time; the more ideas, the better.*
3. *This inhibits the formation of ideas and creativity.*
4. *Building on other's ideas leads to new levels of creativity.*

The tapes provided important information about the time allotted for each lesson and module. The tapes were used to ensure that instructors were given plenty of time to teach the lessons and that the information presented in the lessons was appropriately arranged, and they were also used to make sure that the entire curriculum could be taught within one semester.

These collected surveys and transcribed tapes were used to modify the curriculum accordingly. In the meantime, researchers were also interested in knowing if the curriculum was successful in terms of student satisfaction. Consequently, a student satisfaction survey was designed and administered at the end of the instruction.

<u>Student Satisfaction Survey</u>

The survey was composed of 19 survey questions (see Table 3). Results indicated that the teamwork lessons topped the student satisfaction list, which indicates that students found the teamwork lessons both satisfactory and enjoyable (Chen, 2002). Results also indicated that materials were quite promising for full implementation into a community college curriculum. After the appropriate modifications from the pilot test in place, researchers moved forward to field test the curriculum.

Field Testing the Curriculum

The curriculum was field tested at three community colleges in Iowa, Nebraska, and South Dakota in spring 2003. The field test served a two-fold purpose: to further modify and improve the curriculum and to investigate the effectiveness of the curriculum in teaching teamwork. In order to do this, two different evaluation instruments were developed as follows:

1. *Teamwork Knowledge Test:* A test composed of 22 knowledge-based multiple choice questions about teamwork was developed by the staff to measure students' teamwork knowledge. In order to evaluate the effectiveness of the instruction, a pre-test was

given prior to exposure to the modules and a post-test was given at the end of the instructional period.

2. *Teamwork Skill Assessment:* Fourteen survey-style questions formed by the staff were used to evaluate student progress and improvement through the teamwork curriculum. Students were asked to respond to these five-point scale questions, which offered five options for each of the fourteen questions. The teamwork evaluation was composed of three sections: basic teamwork knowledge (three questions), common teamwork skills (five questions), and team decision-making techniques (six questions). The skill assessment was also conducted twice during the semester, both pre-assessment and post-assessment.

Test Hypotheses

After the completed tests were returned to the project center, an analysis was conducted. A total of 18 students from these three community colleges finished the courses and returned the tests. (Five additional students either dropped the class before the end of the semester or did not return the tests). The data analysis was based upon the completed 18 tests. The testing hypotheses were conducted as follows:

1. *Teamwork Knowledge Test*

This test was used to evaluate students' understanding (knowledge) of teamwork.

A. Test on the percentage of skipped questions

The test was designed with an "I don't know" option included in each test question so students who have a vague

Table 3. The results of the student satisfaction survey (Rating Scale: 5 is excellent, 1 is poor)

Rank	Item	Description	Rating
1.5	17.	The T lessons were helpful to enhance my knowledge for my career.	4.43
1.5	5.	The quantity of material covered was appropriate.	4.43
3	8.	The final project is relevantly designed to apply the whole knowledge of this course.	4.33
5	6.	The homework assignments were relevant.	4.29
5	16.	The T lessons were easy to understand and apply in the final report.	4.29
5	9.	The load of teamwork assignments for each team member were relevantly assigned.	4.29
7	14.	The P lessons were easy to understand and apply in the final project.	4.17
10.5	15.	The P lessons were helpful to enhance my knowledge for my future career.	4.14
10.5	18.	The D lessons were easy to understand and apply in the final project.	4.14
10.5	10.	The assignments were always finished on time.	4.14
10.5	19.	The D lessons were helpful to enhance my knowledge for my future career.	4.14
10.5	4.	The course appeared to be well organized and presented logically.	4.14
10.5	7.	The reading assignments were appropriate.	4.14
14	13.	This course has improved my ability to interpret and evaluate information.	3.86
15	11.	You always got feedback on time when you submitted an assignment for assessment.	3.57
16	12.	The grading system was clear and objective.	3.43

(Note: P stands for Parametric Solid Modeling, T stands for Teamwork, and D stands for Design for Manufacturability) idea about a certain question can honestly show their knowledge. Therefore, the percentage of students choosing option (E), "I don't know", from the total questions will be compared in the pre- and post-tests.

$$H_0: \mu_{E_{TW\_pre}} = \mu_{E_{TW\_post}}$$
$$H_1: \mu_{E_{TW\_pre}} \neq \mu_{E_{TW\_post}}$$

The average of students' percentage of choosing option (E) on the teamwork (TW) pre-test is denoted as

$$\mu_{E_{TW\_pre}} = \frac{\sum_{i=1}^{n} E^i_{TW\_pre}}{n},$$

and that for the post-test is defined as

$$\mu_{E_{TW\_post}} = \frac{\sum_{i=1}^{n} E^i_{TW\_post}}{n},$$

where i and n denote the i^{th} subject and the total number of the subjects tested, respectively.

The percentage of the individual i^{th} student choosing option (E) is given as the following equation for the pre-test and the post-test:

$$E^i_{TW} = \frac{QE^i_{TW}}{QT_{TW}} \times 100\%,$$ where

QE^i_{TW} is the total number of questions that the student selected (E) "I don't know" for the teamwork knowledge test for the subject i, and

QT_{TW} is the total number of questions used to test teamwork knowledge. In this study, QT_{TW} is 22.

In additional to the hypothesis concerning the percentage of choosing option (E) being tested, the hypothesis concerning the percentage of choosing correct answers was also tested as follows.

B. Test on the percentage of correct answers

$$H_0: \mu_{pre\text{-}correct} = \mu_{post\text{-}correct}$$
$$H_1: \mu_{pre\text{-}correct} \neq \mu_{post\text{-}correct}$$

$\mu_{pre\text{-}correct}$ = average percentage of correct answers for pre-test for all the n subjects.

$\mu_{post\text{-}correct}$ = average percentage of correct answers for post-test for all the n subjects.

2. Teamwork Skill Assessment

This test was used to assess students' teamwork skill levels.

Figure 3. Percentages of skipped questions before and after instruction.

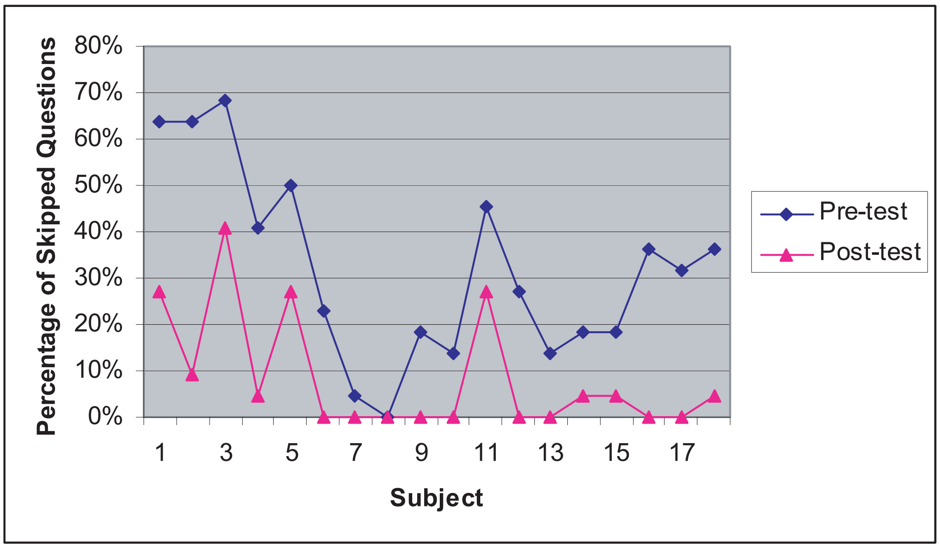
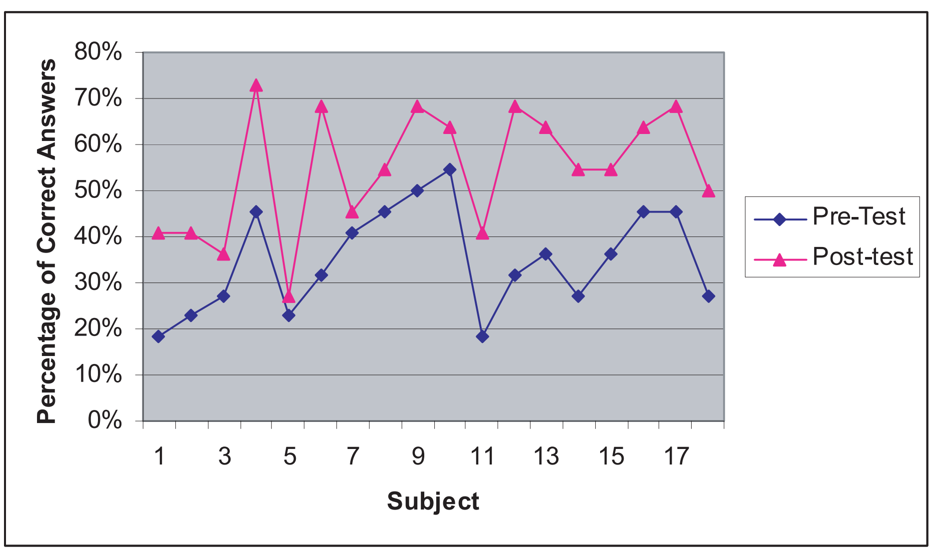


Figure 4. Percentages of correct answers before and after instruction



H_0: $\mu_{pre\text{-}skill} = \mu_{post\text{-}skill}$

H_1: $\mu_{pre\text{-}skill} \neq \mu_{post\text{-}skill}$

$\mu_{pre\text{-}skill}$ = average teamwork skill level for pre-assessment for all the n subjects.

$\mu_{post\text{-}skill}$ = average teamwork skill level for post-assessment for all the n subjects.

Results

1. Teamwork Knowledge Test

The number of skipped ("I don't know") questions. In the pre-test (see Figure 3), two students skipped more than half of the questions, with one student skipping 15 of the 22 questions. The average percentage of skipped questions in the pre-test was 31.82%. The number of skipped questions was much less in the post-test than in the pre-test. In the post-test, most of the students skipped 2 or fewer questions. The average percentage of skipped questions in the post-test dropped to 8.33%. A paired-samples t test showed that participants had skipped significantly fewer questions in the post-test than in the pre-test (t = 7.52, p< .01. See Table 4).

The number of correct answers. Most of the participants showed an increase in the number of correct answers on the post-test, with the exception of one student, who had the same number of correct answers both in the pre-test and the post-test (shown in Figure 4). A paired-samples t test showed that participant performance was better on the post-test than on the pre-test, and the number of correct answers increased significantly from the pre-test to the post-test (t=-8.7, p<.01. See Table 5).

2. Teamwork Skill Assessment

Comparisons between pre and post administration of the Teamwork Skill Assessment are shown in Table 6. Three parts of evaluation are shown separately in the table. The analysis was conducted for the eighteen students who were from these community colleges and finished both the pre-test and the post-test. A paired-samples t test was used for all fifteen questions. It showed that the students improved more on the team-decision skills than any other skills.

Discussion

1. Teamwork Knowledge Test

When taking the pre-instruction teamwork knowledge test, a majority of the students skipped many questions. It indicated that before the instruction students had very limited teamwork knowledge. However, when the post-test was administered, the number of students who skipped questions decreased significantly. The higher answer rate of the post-test is a result of the student's exposure to the curriculum. Because the percentage of correct answers in the post-test is significantly higher, it could be concluded that the curriculum and teaching methods are effective, thus increasing teamwork skills and knowledge among students who are exposed to it. Anther important observation is the low average percentage of correct answers for both the pre-test and the post-test. The average percentages of correct answers for the pre-test and the post-test were only 34.85% and 54.55%. The instructors explained that students were not provided opportunity for study before the post-test, and that might have contributed to the low scores of the post-test.

2. Teamwork Skill Assessment

The results from the teamwork skill assessment were also interesting. The students were asked to respond to the various questions by rating from 1 (little or no awareness of the skill/knowledge/technique), to 5 (much experience/understanding of the skill/knowledge/technique). As shown in Table 6, of the three sections of teamwork evaluation, the most significant difference between the pre-test and the post-test was the section on team decision-making techniques. Students overall showed significant improvement in most of the techniques that were part of the curriculum. However, if different community colleges were analyzed separately, the results could be very different. For example, one of the community colleges expressed opinions of improvement and growth on the three topical areas of Teamwork, but no significant improve-

Table 4. T-test of percentages of skipped questions before and after the instruction.

	Pre-test	Post-test
Mean	31.82%	8.33%
Variance	4.16%	1.66%
Observations	18	18
df	17	
t Stat	7.52	
P(T≤t) two-tail	8.41E-07	
t Critical two-tail	2.11	

Table 5. T-test of correct question rates before and after the instruction

	Pre-test	Post-test
Mean	34.85%	54.55%
Variance	1.26%	1.80%
Observations	18	18
df	17	
t Stat	-8.70	
P(T≤t) two-tail	1.15E-07	
t Critical two-tail	2.11	

ment was observed in their Teamwork knowledge evaluation.

On the other hand, at another community college, statistically significant changes occurred in the students' evaluation of their basic knowledge of Teamwork and in building Team Decision-Making Techniques. Interestingly enough, several students at that institute expressed some dissatisfaction with the learning modules, explaining that they took the course to learn "Inventor and not Teamwork." The diverse responses can only be explained that different instructors delivered the same curriculum differently: instructors might have different levels of the knowledge and skills of the subject areas, and their personality or their attitude toward the contents might greatly affect their students' attitudes.

Conclusion

This study investigated new ways to incorporate teamwork knowledge and skills in technical education with both the pilot and field tests and also examined the outcome of the field test in spring 2003 with two assessment instruments: the teamwork knowledge test and the teamwork skill assessment. Results comparing teamwork knowledge before and after about twelve and a half hours of exposure to the teamwork part of curriculum indicated that students gained comprehensive teamwork skills and knowledge. The result of the teamwork skills assessment also indicated significant improvement among students in various skills and techniques. These findings suggest that incorporating teamwork skills and knowledge into the curriculum via lesson and module content and practical, realistic assignments may be beneficial to students who seek to have the competitive edge in the manufacturing industry. However, it is also suggested that instructors play the crucial role in the success of students' teamwork training and instructors need more professional training on the subject before they could positively affect students.

The success of teamwork-infused curriculum at different community colleges in the Midwest provides the possibility for further studies in the following areas:

1. The effectiveness of teaching the same teamwork content to community college students in different locations and with different backgrounds
2. The effectiveness of teaching the same teamwork content to technical education students in

Table 6. Comparisons between pre-and post administration of the Teamwork Skill Assessment

I. Basic Knowledge	Pre-assessment		Post-assessment			
	Mean	Std Dev	Mean	Std Dev	t	p
A. Modern manufacturing organizations weigh teamwork	2.88	1.4	3.94	0.9	3.78	.01
B. Teamwork skills are ranked the most important qualification for technicians	3.06	1.4	3.44	1.0	0.97	.35
C. There are many types of teams in the manufacturing world	2.81	1.5	3.63	1.2	1.89	.08

II. Common Teamwork Skills	Pre-assessment		Post-assessment			
	Mean	Std Dev	Mean	Std Dev	t	p
A. Construct a meeting agenda	2.81	1.1	3.69	1.0	2.33	.03
B. Record meeting minutes	2.81	1.1	3.50	1.0	1.90	.08
C. Become an effective and contributing member	4.06	0.8	4.38	1.0	1.23	.24
D. Solve team conflicts or team problems	3.94	0.8	4.06	0.8	0.49	.63
E. Properly communicate with others	4.38	0.6	4.19	0.9	-0.82	.42

III. Team Decision-Making Techniques	Pre-assessment		Post-assessment			
	Mean	Std Dev	Mean	Std Dev	t	p
A. Brainstorming Technique	4.13	1.2	4.31	0.8	.59	.57
B. Nominal Group Technique	2.63	1.4	3.63	0.8	2.83	.01
C. Delphi Technique	1.81	1.1	3.31	1.1	4.11	.00
D. Paired-Choice Matrix Technique	2.06	1.4	3.56	1.2	3.67	.00
E. Consensus Card Technique	2.19	1.6	3.56	1.4	3.22	.01
F. Criteria Rating Technique	2.56	1.5	3.25	1.3	1.79	.09

different academic sects, such as four-year universities and high schools
3. The effectiveness of teaching the same teamwork contents on the web

The limited scope of the research also suggests that an extended study on teamwork in the following areas will be necessary:

1. Instructor training on teamwork and its impacts on students' teamwork learning
2. Appropriate length of exposure, retention of knowledge, use of the teamwork skills by students in other manufacturing courses, and application in other NAIT curriculums.

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