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Jerry Streichler

Editor

Dennis Cheek

Board of Editors

E. Stephanie Atkinson
University of Sunderland
School of Education
Hammerton Hall, Gray Rd.
Sunderland, U.K. SR2-8JB
stephanie.atkinson@sunderland.ac.uk

Linda Rae Markert
200 Poucher Hall
State University of New York
at Oswego
Oswego, NY 13126-3599
315.341.5407
markert@oswego.edu

Wan-Lee Cheng
Department of Design and Industry
San Francisco State University
1600 Holloway Ave.
San Francisco, CA 94132
415.338.2211
fax: 415.338.7770
wlcheng@sfsu.edu

Howard E. Middleton
School of Vocational Technology
and Arts Education
Faculty of Education
Griffith University
Nathan 4111 Queensland
Australia
61.7.3875.5724
fax: 61.7.3875.6868
h.middleton@mailbox.gu.edu.au

David Devier
University of Cincinnati
Clermont College
4200 Clermont College Drive
Batavia, OH 45103
513.732.5209
fax: 513.732.5275
David.Devier@uc.edu

Sam C. Obi
Department of Technology
San Jose State University
One Washington Square
San Jose, CA 95192-0061
408.924.3218
fax: 408.924.3198
sobi@email.sjsu.edu

Michael J. Dyrenfurth
Department of Industrial Technology
Purdue University
1410 Knoy Hall, Room 461
West Lafayette, IN 47907-1410
765.496.1203
fax: 765.494.0486
mjdynfurth@tech.purdue.edu

Christopher J. Shelley CMfgE
W. L. Gore & Associates
705 Guido Dr.
Middletown, DE 19709
302.598.7289
cshelley@wlgore.com

Marie Kraska
Educational Foundations, Leadership,
and Technology
Auburn University
4036 Haley Center
Auburn University, AL 36849-5221
334.844.4460
fax: 334.844.3072
kraskamf@auburn.edu

Xeushu Song
Department of Technology
Northern Illinois University
Dekalb, IL 60115-2854
815.753.1349
fax: 815.753.3702
q20xs1@corn.cso.niu.edu

David Devier
(representing the Board of Directors)

Staff for this Issue

Editorial Consultants

Nancy Hoose
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Art & Layout

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Dr. Marvin Sarapin
Department of Technology
Kean University
Union, NJ 07083
908.737.3500
fax: 908.737.3505
msarapin@turbo.kean.edu

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Department of Mathematics, Science, &
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North Carolina State University
Raleigh, NC 27695-7801
919.515.1742
fax: 919.515.6892
robert_wenig@ncsu.edu

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David Devier
University of Cincinnati, Clermont College
4200 Clermont College Drive
Batavia, OH 45103
513.732.5209
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David.Devier@uc.edu

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Kennard G. Larson
Dept. of Industrial Technology
University of Nebraska at Kearney
905 West 25th Street
Kearney, NE 68849
308.865.8504
fax: 308.865.8976
larsonk@unk.edu

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James Edwards
Department of Design & Industry
San Francisco State University
1600 Holloway Avenue
San Francisco, CA 94132
415.338.7896
fax: 415.338.7770
jge@sfsu.edu

Associate Executive Director for Information and Communication

Dr. Dennis Cheek
John Templeton Foundation
5 Radnor Corp. Ctr., Suite 100
Radnor, PA 19087
610.687.8942
fax: 610.687.8961
dcheek@templeton.org

Associate Executive Director for Community and Technical Colleges

Jerry C. Olson
Technology Building
Bowling Green State University
Bowling Green, Ohio 43403
419.372.0378
fax: 419.372.9502
jcolson@bgnet.bgsu.edu

Associate Executive Director for International Affairs

Michael Dyrenfurth
School of Technology
Purdue University
Room 461, Knoy Hall
West Lafayette, IN 47907-1410
765.496.1203
fax: 765.494.0486
mjdynfurth@tech.purdue.edu

Executive Director

Jerry Streichler
Technology Building
Bowling Green State University
Bowling Green, Ohio 43403
419.372.2425
fax: 419.372.9502
jots@bgnet.bgsu.edu

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Learning & Growing: Integrating Technology Undergraduates into the Development of an Industrial Case Study

Kathryne Newton and Edie Schmidt

A national industrial distribution association approached us to develop a case study for its association members. The national association assumed responsibility for identifying educational needs of upper level, mid level, and lower level personnel in the industry. In the previous year, a case study had been developed to educate upper level managers in the strategic nature of distribution in their industry. The association found that upper level management had a great learning experience and wanted lower level workers to have the same opportunity to refine and enhance their knowledge on making inventory and warehousing decisions. The project objective was to develop a case study that would be used in a weekend workshop to educate operations and customer service personnel involved in making logistics-related decisions. The mid level operations and customer service personnel were to attend a two-day workshop to learn basic terminology, analyze the case study, and refine their current knowledge surrounding their job duties.

This article describes the process of developing a case study for a national trade association and integrating learning opportunities for undergraduate technology students at Purdue University. The needs assessment phase of this project became an Inventory and Warehouse Management course project. The educational goal for the weekend industrial workshop, based on the case study, was to accomplish the following:

- Be valuable for companies with \$5 million to \$400 million in sales.
- Address the environment where employees typically handle 3,000 to 8,000 stock-keeping units.
- Teach the attendees in a highly participative setting.
- Incorporate small group activities.

The educational materials to be developed for the weekend workshop were a new case study, workbook, supporting reading materials, PowerPoint presentation, glossary of common terms, and an evaluation instrument.

The topic areas to be covered in the case study and the weekend workshop were:

- Inventory management and control.
- Product backorder and returned goods.
- Facility selection and layout.
- New product introduction.
- Order fulfillment routines.
- Selection of transportation modes.
- Multiple branch issues.
- New technology adoption.
- Human resource management.
- Key productivity measures.
- International issues.

Background on Educational Component

One of the first steps in the case study development (to be described more completely under the methodology section) was to research the needs of the trade association members. The students accomplished this by developing and analyzing results of a survey administered to the industrial distribution trade association members regarding their logistics and operational educational needs. This task proved a valuable opportunity to integrate the project with a scheduled junior-level class at Purdue University in the School of Technology. The School of Technology (and the Industrial Technology Department) prides itself on teaching students applied concepts via hands-on learning, experiential exercises. Just as important is the need to address what Savage (2001) called “the challenge of dealing with the ‘Moving Target’ of Technology” (p. 9). Faculty must be committed to providing opportunities for relevant content in “learner contemporary” concepts and providing challenging coursework for students. What better chance to teach the concepts and topic areas identified earlier than having the Inventory and Warehouse Management students apply what they learn in the class to this project? The course content covered all topic areas necessary for the case study workshop, which made the case study development a great learning and teaching opportunity.

Faculty and students have evolved to the point where they value learning through interactive assignments. The objective of this project was to enhance students' learning through increasing knowledge in the following three areas: (a) systems knowledge; (b) topical areas such as inventory management, facility layout, product backorders, and other topical areas identified earlier for companies hiring industrial technology students; and c) reflectivity, which involves comparing one's thinking to experts and peers.

If students are to develop systems understanding, then they must engage in all aspects of the system, which includes elements, relationships among elements, operations that describe how the elements interact, and patterns or rules that govern the preceding relationships and operations (Lesh & Kelly, 2000). For example, topics in the Inventory and Warehouse Management class include new product introduction, order fulfillment, selection of transportation modes, new technology adoption, and so on. Each topic listed above is in itself a subsystem. These subsystems comprise the industrial distribution and manufacturing system.

Each topic must be understood along with the relationships to other topics and the rules and patterns that govern the complex industrial organization. By mapping out the needs of industrial distributors in several topic areas, students are able to attain systems knowledge of distribution topics.

The Society of Manufacturing Engineers (1999) worked with industry and colleges and universities to analyze the skills and knowledge necessary for college graduates to become effective workers in the manufacturing industry. The study identified 15 competency gaps including:

- Problem-solving abilities.
- Fundamental topic knowledge such as manufacturing systems, logistics, and product/process design.

This project gave students an opportunity to delve deeper into these topics by applying course topics and learning additional information about distributors' problems and issues.

Another learning objective of coursework is the ability to think reflectively, where reflective thinking involves actively monitoring, evaluating, and modifying one's thinking and comparing it to both expert models and peers (Lin, Hmelo, Kinzer, & Secules, 1999). This project gave students a chance to compare their beliefs about current issues in warehouse and inventory with distributor beliefs on the same issues.

Methodology

Case studies are valuable learning tools because the case study describes a real situation for learners. According to Smith and Ragan (1999), case studies are similar to simulations in that they present a realistic situation and require learners to respond as if they were responsible for solving the problem. "Case studies also require learners to select and manipulate multiple principles in order to solve problems" (Smith & Ragan, 1999, p. 145). In order to make this case study "real" to the inventory and warehouse personnel, the case study materials were developed using these four main steps:

1. Research the needs of the trade association members, with undergraduate Purdue students assisting faculty.
2. Establish an overall model for the case study.
3. Evaluate the case study first draft with assistance of association board members.
4. Finalize the case study and develop the supporting educational materials.

Step 1: Research the Needs of the Trade Association Members

The students had an opportunity to apply what they learned in class by developing a survey instrument to be administered to trade association industrial distribution members. The students were assigned a semester-long group project, with four students per group. The 1. Develop a list of questions for three topic areas from the suggested list above (inventory management and control, productivity, etc.).

2. Contact two distributors and document the results of their responses.
3. Generate a written report.
4. Present recommendations and suggestions to the class.

Each student group was asked to pick three topic areas from the list of topic areas to be covered in the case study. The students developed a list of questions to ask distributor personnel related to the topic area. The questions captured the information needed for the study. In order to validate the questions, the students individually assessed the questions and responded to the question to determine the types of responses to expect. Then, as a student group, the questions and responses were analyzed. Were the answers valuable? Were responses inconsistent? (i.e., Did one person respond completely differently from another person?), or Was the question unclear? Problem areas for each of the questions were then identified. The student groups then finalized questions with tables of responses expected from the distributors.

Example for topic area: Backorders and Returned Goods

Question: What is your policy for handling product backorders?

Answer 1: The backorders are filled as early as possible.

Answer 2: What is a backorder?

Answer 3: Backorders are filled before new orders are filled.

The students determined that different respondents might see each question uniquely different, so identifying some specific problems with the questions was necessary. Continuing on with this example, the students identified these problem areas for the backorder and returned goods topic area:

1. What is meant by backorders?
2. Is the prioritization of backorders the key?
3. The term policy is ambiguous.

The problem areas then forced the members of the student group to reevaluate their objective in asking the question and develop a more complete question. In this case the student group determined the following question would capture the essence of the information they were seeking:

When your company has an order that cannot be filled immediately from on-hand inventory, how do you make sure the customer gets its order?

The output from each student group was a survey customized for three topic areas. The trade association then gave the students a list of distributors to contact, and the students began the process of contacting the distributors via email and fax.

The student groups were responsible for contacting three to five distributors each and documenting the distributor responses by organizing the data in tables and charts. These results clearly identified key issues and problem areas for the distributors' case study and also statistics for most common responses and unusual responses. Another benefit from the results was the discovery of special jargon and terminology used in the industry. The students collected data from over 40 distributors, with at least four distributor respondents per topic area. For each topic area, the students aggregated the differences and similarities of responses. These similarities and differences in operating procedure were highlighted by size of company, product type, number of stockkeeping units, and location. This information gave an even clearer picture of the audience for the weekend workshop.

The data collection process was not over yet, however. We then visited distributor warehouses in the industry to further validate the survey results. On-site visits with different-sized distributors were particularly valuable for verification of the issues from the distributor survey responses. Although the distributors were in the same industry, each was unique in how it conducted business, the knowledge level of warehouse personnel, and terminology used by each employee. Lastly, these site visits confirmed that the workshop would have to be conducted at a level consistent with the typical warehouse and inventory personnel education and experience level. Given the varied backgrounds of the personnel, the workshop was developed using adult learning principles. Characteristics of adult learners are (a) their experience is a foundation for learning but each adult learner is unique in his/her needs because of age, ability, work experience, and cultural background, and (b) adult learners expect class time to be well spent and help

them immediately apply their knowledge to their daily lives (Wisma, 2001).

Step 2: Establish an Overall Model of the Case Study

The data collection site visit phase identified key competencies and areas for improvement for distributors in the industry. The six-page case study incorporated the human element with main characters the inventory and warehouse personnel would relate to, as well as key problems likely to be experienced in each company. The case was a scenario depicting problems that a “traditional” warehouse supervisor faced when the company was acquired by a much larger “world-class” parent company. The case described many operational issues that had to be corrected in order to meet the new standards for warehouse operations, including quantitative measures that provided for the basis of analysis and problem-solving exercises by participants.

Step 3: Evaluation

The six-page “Brees Floor Covering Case” and initial workshop objectives were forwarded to the industrial distribution association officers for feedback. Comments and suggestions were incorporated into the case study document.

Step 4: Finalize the Case Study

The workshop educational materials were finalized, including the case study, instructor’s manual, supplemental readings, glossary of common terms, and supporting multimedia materials. The in-class activities and workshop schedule were developed using the following adult learning principles (Wisma, 2001):

Adults need to know why they need to learn something.

- Adults need to learn by experimentation.

- Adults approach learning as problem solving.
- Adults learn best when the topic is of immediate value.
- Adults view learning as an active process in the construction of meaning.

Findings

Writing a case study proved to be a great opportunity for us in several areas. We were able to update our working knowledge of a specific industry. The teaching of undergraduate technology students was enhanced through a sharing of responsibilities with the students. An active learning environment linked with the real world was realized through this hands-on project. An end goal for the workshop was to motivate inventory and warehouse management personnel to learn more about their industry and new techniques in their field. This case will also be valuable as a learning aid in future warehouse and inventory management classes.

We challenge educators, graduates, students, industrial representatives, and others interested in technology education to engage in educational projects of this nature. Pick an operational area or industry to research and develop a case study. The benefits and challenges are many—a journey not to be missed!

Dr. Kathryne Newton is an Associate Professor in the Department of Industrial Technology at Purdue University. She is a member of the Gamma Rho Chapter of Epsilon Pi Tau.

Dr. Edie Schmidt is an Assistant Professor in the Department of Industrial Technology at Purdue University. She is a member of the Gamma Rho Chapter of Epsilon Pi Tau.

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Using Multimedia to Teach a Class on Technology and Society

Patricia Ryaby Backer

There has been considerable discussion in general educational publications about the value of instructional technology, in particular multimedia- or Web-based instruction. Much of the published work thus far has described various features of multimedia systems in an anecdotal manner rather than focusing on an evaluation of multimedia and its use in the university setting (Windschitl, 1998). In all of the discussion on multimedia, the nature of multimedia and learning using multimedia are interlinked. That is, most authors attribute positive pedagogical implications to multimedia merely because of its nature or structure (Campos, Salcedo, & Rossel, 1996; Fontana, 1993). This perspective combines two aspects of learning, what is learned and how it is learned, into one entity. This pedagogical perspective has some foundation in the literature (Bayne & Land, 2000; Fenley, 1998; Plowman, 1996; Wild & Quinn, 1998). There have been long-standing claims that students learn faster and retain more information the more they are involved in the learning process (Liu & Hsiao, 2001; Royer & Royer, 2002). Therefore, the more students interact, the more they will learn. From a theoretical perspective, Hamilton (1990) saw the curriculum as a process that should not separate what is learned from how it is learned. This duality is the fundamental identity of multimedia.

By its nature, multimedia-based learning is

more complex than traditional lecture instruction. According to Mandl (1998), there are a number of factors to consider in designing a model for complex learning. First, there must be appropriate support for complex learning, for example, the development of a multimedia structure by a teacher or peer. Second, there is the need to prepare students for a new learning environment. One major problem with innovative teaching methodologies is that there is a lack of fit between the innovative instruction and the evaluative measures (i.e., tests and examinations). The multimedia and evaluation methods should complement each other and enhance the overall learning environment.

Because of the unique nature of multimedia, problems exist with the delivery of instruction. Jonassen (1991) described three major problems that occur in multimedia: navigation (users get lost in the document), difficulty in integrating the presented information into personal knowledge structures, and cognitive overload. Also, he stated that a learner's interactions within a multimedia environment are not predictable and are less deterministic than other modes of instruction. Other researchers (Babu, Suni, & Rasmussen, 1998; Cordell, 1991) have found that a student's learning style affects achievement on multimedia-based learning. Divergers (using Kolb's learning style preference) were found to improve more on posttest

measures than those who have other learning styles. This could lead one to state that the successful use of hypermedia requires nonlinear thinking on the part of the user—this type of thinking may not be successful for all users.

It is crucial to understand the social aspects of teaching and learning with multimedia. Multimedia and Web-based courses create a different educational environment than is seen in a traditional classroom. Students bring their cultural backgrounds, university expectations, and personal computer experiences into all their learning environments, including the multimedia experience. In class, however, the instructor can adapt to students more easily than in an online environment. In an online environment, the face-to-face interaction is diminished or lost, making it more difficult for the faculty member to interpret the nonverbal cues from the students. This course is taught at San José State University (SJSU), which has an extremely diverse student body. Since learning can not be separated from the learners' historical and cultural backgrounds (O'Loughlin, 1992), this level of diversity provides additional challenges to the use of multimedia in a course.

Design and Development of the Multimedia Modules

As designer of this project, I applied for a SJSU Improvement of Instruction grant and was awarded one for the 1994 calendar year. The course chosen for this project was Technology and Civilization, a general education science-technology-society (STS) course. This course is required for industrial technology majors in the College of Engineering as well as being a popular advanced general education (GE) course for other majors at SJSU.

The GE program at SJSU (1998) is different from many in the United States. Instead of specifying a specific series of courses as part of the GE of each student, SJSU has five core GE areas (skills, science, humanities and arts, social sciences, and human understanding and development). In addition, every SJSU student must take advanced GE courses in four areas: earth and environment; self, society, and equality in the U.S.; culture, civilization, and global understanding; and written communication. Any depart-

ment may propose a course for any area of GE. The course involved in this multimedia development process was approved as an advanced GE course in the earth and environment area until spring 2000. In fall 2000, after a revision of the university GE program, the course was approved in another advanced GE area (culture, civilization, and global understanding) where it remains an approved course today.

Before any multimedia development work was done, a faculty panel revised the course syllabus. Originally, there were eight units in the course. During the discussions of the course by the faculty, there was a general consensus that there was too much course content. So, the content of the course was revised to reduce the number of units to six. After the course syllabus and content were determined, the development work began on the multimedia modules.

The first decision in the multimedia development process was the choice of authoring environment; the package chosen was Authorware for Windows. In addition, other planning decisions included discussions with the university's central computing facilities related to the use of e-mail by students and the most effective way to manage the e-mail interactions among students and with the faculty coordinator and also determining the best way to include videotaped materials: on videotapes, videodisks, or as a part of the multimedia environment using CD-ROMs.

The primary outcome of this project was self-paced modules on CD-ROMs that allowed students to explore the topics presented in this class on their own, while being able to correspond with other students and faculty by e-mail. Two units were chosen for multimedia development: Unit 1. The Nature of Science and Technology, and Unit 2. Technology and Work. The primary instruction for these modules was by a multimedia-based document that provided an organizational structure for the course. In addition, textbooks, readings, and videotapes were required by the class.

Each unit in the course was developed as a series of files using Authorware, with each unit having an introductory section (file) followed by

four to eight sections (files) in each unit. At the end of each section, students were required to complete a class activity and submit the activity to their professor by e-mail. The individual files were linked by hypertext commands so that the student would not have to run the individual files separately. The multimedia was converted to an executable version for student use. The multimedia modules included graphics, video clips, and animations that were related to the text presented in each section. The media for each section was chosen to build upon the text and was positioned on the same screen. According to researchers (Mayer, 1989; Mayer & Sims, 1994), verbal information and pictorial information are more effective if they are presented nearby rather than on different screens.

The design and development phase of this multimedia course spanned seven years, from June 1994 to May 2001. During this seven-year period, I generated five distinct versions of the multimedia modules. At each stage of the development process, the modules were evaluated by all the faculty teaching the course as well as by students in the course. The significant changes and the evaluation for each version are discussed in the sections below.

Version 1

The first version of Units 1 and 2 was used in fall 1994 and spring 1995 lecture courses as presentation modules although the entire multimedia course was not finished. The multimedia modules were structured using a modified hierarchical hypermedia. The most significant differences between Unit 1 and Unit 2 at this time relate to their navigational structures. Unit 1, designed first, was predominately linear although some of the sections contained a menu screen. As compared to Unit 1, Unit 2 was less linear in structure and the information was grouped into chunks with page numbers in each chunk.

Selected students and faculty teaching the course evaluated the modules in order to further refine these multimedia documents. In initial field tests with several students, many students reported problems with navigating (getting lost in the document) through the modules. This, according to Jonassen (1991), is one of the three

major problems that occur in multimedia. Other feedback was obtained from instructional designers at an international conference in 1996 when I presented the development and design of the first version of these multimedia modules.

Version 2

After gathering several semesters of data on Version 1 of the multimedia documents for Units 1 and 2, Version 2 of the multimedia was created in 1999. Version 2 was a minor revision that focused on the addition of enhancements including a pull-down menu to allow students to end each section in the middle and to return later to where they had left off, a change in font from serif to sanserif to increase readability, and addition of a student log-in subroutine to allow tracking of student pathways through the multimedia.

During the summer session 1999, Version 2 was field tested in one section of the class with 14 students. The students were randomly assigned to two groups: Group 1 completed the multimedia module on Unit 1 (The Nature of Science and Technology) and Group 2 completed the multimedia module on Unit 2 (Technology and Work). The summer session was organized into a one-week class with eight hours of class each day. Day 1 of the class was devoted to Unit 1 and Day 2 of the class was devoted to Unit 2. On their randomly assigned multimedia day, the students were sent to a computer laboratory where each student was assigned a computer and given a CD-ROM. Instead of attending class, they stayed in the computer laboratory and completed the multimedia. In lieu of their "regular" classwork, they completed the online class activities at the end of each section of the multimedia and submitted these to their instructor.

On the first day of class, the students were given a demographic student profile that asked their age, experience and time spent daily on a computer, and major. Also, the students were given two computer attitude questionnaires. The first was an open-ended survey with three questions designed to find out how they defined computers and their love-hate relationship with computers. This survey was developed by Morse and Daiute (1992) and was field tested by this researcher (Backer & Yabu, 1994) in a previous

study. The second survey was a revised version of Oetting's (Martin, 1998) Computer Anxiety Scale (COMPAS). These two computer surveys were given to control for any variability in the computer anxiety and/or attitudes of the two treatment groups.

In addition to the computer anxiety/attitudes surveys, all the students were given pretests for both Units 1 and 2 before either class instruction or multimedia instruction began. On the last day of class, the students were given the posttests for both units. The pretest and posttest for Unit 1 (The Nature of Science and Technology) had eight questions that were selected by faculty teaching the course as representative of the information covered in the unit. The pretest and posttest for Unit 2 (Technology and Work) had 11 questions also selected by faculty.

Students in the two treatment groups had an equivalent mean age (27 years) and similar amounts of time reported as spent on computers each day (3.09 hours/day for Group 1 versus 2.95 hours/day for Group 2). In addition, both groups showed a wide range of computer anxiety on the COMPAS; however, the mean computer anxiety score for each group was equivalent ($M = 108$ for Group 1 versus $M = 107$ for Group 2). In performance, the two treatment groups appeared to be distinctly different. Based upon the ANOVA for Unit 1, there was no difference in student performance when comparing the multimedia-based instruction with the traditional classroom instruction. The students taking the multimedia-based instruction for Unit 1, in fact, did worse on the posttest than those students in the traditional classroom. However, since the students in Group 1 had consistently worse overall performance than students in Group 2, this result is inconclusive. The results from Unit 2 were different than those of Unit 1. The results showed that both groups had significantly higher scores on the posttest than on the pretest. An ANOVA comparing the pre- and posttest scores showed an F value of 39.84 ($p < .001$). As for Unit 1, Group 2 (the students taking the multimedia for Unit 2) performed better on the posttest than did Group 1 although the difference was much less ($M = 7.7$ for Group 1; $M = 8.4$ for Group 2).

Overall, the multimedia for Unit 2 led to higher student achievement than either the "regular" classroom instruction or the multimedia for Unit 1. The qualitative evaluation of the multimedia modules was examined to see if there were any commonalities that indicated why the Unit 2 multimedia was more successful. Ten of the 14 students completed a qualitative evaluation of the multimedia modules. All 10 students liked the multimedia modules for the class. As one student stated, "I liked the video interactions, they allowed me to comprehend the material better." Another student noted, "I found the multimedia portion of this class to be very impressive. I really enjoyed the freedom and convenience of the CD ROM. The content allowed me to gain specific knowledge on specific subjects that I would not have otherwise known about." Overall, the students taking the Unit 1 multimedia found they had a harder time navigating through the material. Since Version 2 of the Unit 1 multimedia presented the material in a linear fashion, the students did not know where they were in the course of the lesson. Also, they noted that it was difficult for them to review previous material. The students who took the Unit 2 multimedia complained about the amount of material in each section.

Version 3

Overall, there appeared to be several issues related to the multimedia modules. Both the Unit 1 and Unit 2 feedback from Version 2 related to two multimedia design issues: navigation and narrative structure. To increase student control of the learning environment, controls were added to all video clips in both Unit 1 and Unit 2 that allowed students to pause, play, and stop videos. Also, each section in Unit 1 and Unit 2 included a class activity at the end so that the students could achieve closure on each topic.

It was evident from the qualitative and student outcomes that the navigational structure of Unit 2 was better than that of Unit 1. However, a problem still existed with the narrative structure. Because the information was not presented in a clear, organized manner, the students' learning was adversely affected. As Laurillard (1998) pointed out in her research, "learners working on interactive media with no clear narrative structure display learning behaviour [sic] that is gen-

erally unfocused and inconclusive” (p. 231). The chunking of information is interlinked with the narrative structure of multimedia. Because the teacher-storyteller is remote from the student-listener, the design of the multimedia and the chunking of its content need to be more robust.

At this time, it was decided to complete a structural change of Unit 2 to address both the issues of chunking and narrative structure before making any substantive revisions to Unit 1. The three sections of Unit 2 were reorganized completely and divided into eight parts: The Industrial Revolution, Industrialization of Society in the 19th Century, Workplace of 1900, Scientific Management, The Development of the Assembly Line, Consumerism in the West, Nature of Work Today, and How Does Technology Affect the Workplace? The content in each section was revised so that the students could reread a section without restarting from the beginning. This reorganization provided a better narrative structure and, at the same time, increased learner control. As Steinberg (1989) found, increasing learner control can make the learning experience more motivating as well as increase student learning.

Version 3 was used in the winter 2001 class as a replacement for the in-class instruction. On the first day of class, the students were given the multimedia CD-ROMs for both units and were asked to complete them at home or in one of the department’s computer labs. Each weekday during the winter term, students would e-mail the appropriate class activities to their instructor. A review of the class activities submitted by the students indicated that they learned the subject matter for both units. After the multimedia modules were finished, the students returned to the classroom. Since all the students in the class used the multimedia modules, their performance was compared with a previous winter 1999 class (taught entirely in a “traditional” mode). The winter 2001 class ($M = 84$), on average, achieved higher grades on the final exam than did the winter 1999 class ($M = 78$), but the results were not significant. Results from the qualitative evaluation showed no more complaints about navigation or the amount of content in each section for Unit 2 and indicated that the students viewed the experience in a pos-

itive light. Overall, the students preferred the navigational design of Unit 2 to that of Unit 1. Overwhelmingly, the comments were positive about the multimedia modules. There was one significant student suggestion for this version of the multimedia. The students wanted the ability to print out the text easily. (Since this multimedia was constructed using Authorware, students could not “cut and paste” the text on the screen as they were accustomed to doing on the Web.)

Versions 4 and 5

Version 4 was the last major revision of these multimedia modules. The work for this revision centered on Unit 1. Based upon the feedback from Version 3, Unit 1 was completely redesigned to follow the “look and feel” and structure of Unit 2. The new Unit 1 was less linear and the information was grouped into chunks with page numbers in each chunk. The existing six parts for Unit 1 were re-divided into seven sections: the old section *What Is Science and Technology?* was divided into two sections: *What Is Science?* and *What Is Technology?* Also, all the video clips for both units were recaptured at higher resolution and converted to QuickTime format in Unit 1. I added a new pull-down menu with an option to view the text in each section as a text file. (This was done to address students’ complaint that they could not easily print the text.) Also, the class activities were revised and a few links to Web sites were added. All the movies in both units were changed to allow student use of a standard Quicktime control bar. The multimedia was ported to the Macintosh platform so that students could use either a Windows or MAC computer to view the material.

Beginning in the fall 2000 semester, all instructors in all sections began to use the multimedia modules in their classes. Most of the instructors used the multimedia as self-paced learning while other instructors used the modules as a supplement to in-class discussion sessions. Since all of the instructors used the modules, there was a greater amount of feedback from both the instructors and the students. This dissemination created additional challenges for the instructor and author (who also served as the course coordinator). As Zirkle and Ourand (1999) found, teaching a course through multiple deliv-

VERSION	MAJOR CHANGES
Version 1 November 1994	Six parts: (a) What Is Science and Technology? (b) What Is Scientific and Technological Literacy? (c) The Scientific Method, (d) Attitudes Toward Technology, (e) Technology Dependence and Technology Traps, and (f) Impact of Technology on Society. Each part predominately linear, some contain a menu screen. All sections loop back to the menu screen. Limited student control over videos. Files named numerically. Each part contains a cumulating class activity.
Version 2 August 1999	Minor revision. Same basic structure as Version 1. Added navigation pull-down menus. Changed fonts to sanserif. Added student login to track information. Files given more descriptive names.
Version 3 November 2000	Redesigned color scheme and fonts. Added controls to all videos; controls allow students to pause, play, and stop videos. Redesigned class activities.
Version 4 June 2000	Seven parts: What is Science and Technology? was divided into two sections: What Is Science? and What Is Technology? Completely redesigned the structure to follow the “look” and structure of Unit 2. Less linear, information is grouped into larger chunks with page numbers in each chunk. Added a new pull-down menu with option to view the text in each section as a text file. Revised the class activities and added a few links to Web sites. Revised colors and fonts so that entire unit has a consistent color scheme. Recaptured all video clips at higher resolution and converted to QuickTime format. Changed all movie clips from movie icon to QuickTime media with control bar.
Version 5 May 2001	Minor revision. Same basic structure as Version 4. Revised content of several sections.

ery formats, in this case multimedia as well as lecture, requires new expertise on the part of faculty. During the fall 2000 semester, there were several technical issues that needed to be resolved with various faculty. As faculty experience with the multimedia increased each semester, there were fewer problems and less faculty anxiety about using these modules as an integral part of their class.

The last revision of the multimedia modules, Version 5, was minor and focused on updating and revising the content in several sections. For four semesters, all the faculty currently teaching this course have used the multimedia in their classes. Now, these multimedia modules are required for all sections of this course. There are plans to update the content in each multimedia every two years.

A Worthwhile Effort

The development process of multimedia modules for a GE course at SJSU was very long and complex. In fact, the development cycle of these multimedia modules spanned seven years and five separate revisions. When first proposed in 1994, the process was envisioned as a one-year project. However, there were many twists and turns along the way. Because of the nature of multimedia, there is the expectation that changes in multimedia material will happen frequently. These changes, whether small or large, can be very time consuming. For example, the relatively small change to add a pull-down menu to allow students to print the text (made in Version 4) took six weeks because of the number and size of the multimedia files.

VERSION	MAJOR CHANGES
Version 1 November 1994	Three parts: (a) History of Technology and Work, (b) Nature of Work in the 20th Century, and (c) How Does Technology Affect the Workplace? Each part contains a menu screen. All sections loop back to the menu screen. Less linear, information is grouped into larger chunks with page numbers in each chunk. Navigation pull-down menus. Added student log-in to track information. Files named numerically. Each part contains a cumulating class activity.
Version 2 August 1999	Minor revision. Divided into four parts. The History of Technology and Work section was split into two files: The Industrial Revolution and Industrialization of Society. Same overall content structure as Version 1. Added student log-in to track information. Files given more descriptive names.
Version 3 November 2000	Reorganized completely and divided into eight parts: The Industrial Revolution, Industrialization of Society in the 19th Century, Workplace of 1900, Scientific Management, The Development of the Assembly Line, Consumerism in the West, Nature of Work Today, and How Does Technology Affect the Workplace? Added Previous Section and Next Section buttons to all content chunks (allows students to reread a section without restarting from the beginning). Added more content to the sections. Added controls to all videos; controls allow students to pause, play, and stop videos. Changed font. Redesigned class activities. Added additional video clips. Recaptured all video clips at higher resolution and converted to QuickTime format.
Version 4 June 2000	Minor revision. Added a new pull-down menu with option to view the text in each section as a text file. Revised the class activities and added a few links to Web sites. Revised colors and fonts so that entire unit has a consistent color scheme. Changed all movie clips from movie icon to QuickTime media with control bar.
Version 5 May 2001	Minor revision. Revised content in two sections: Nature of Work Today and How Does Technology Affect the Workplace?

The original development of the first version of the multimedia modules took longer than had been estimated. Also, there was a significant time gap between the publication of Versions 1 and 2. This delay can be attributed to several factors—fatigue with multimedia being the primary one. This factor is infrequently mentioned in the literature. It takes an extraordinary amount of time to develop fully functional multimedia modules. Another cause for the time delay between versions was a university restructuring of the GE program—this multimedia project was put on hold until the class was recertified for GE. A consistent time constraint existed throughout the life of this project. I also work at a teaching institution where the course load is typically four different classes each semester (12 units). This heavy teaching load reduced the amount of time available to work on

the multimedia modules during the academic year.

Technical problems constantly occur in multimedia development. And, it seems that often the solution to one technical problem leads to a new one. The story of the video clips in this multimedia project highlight this sort of technical problem. Originally, most of the video clips were captured at 120 X 160 screen resolution in 1994–1995 at 10–15 fps. Then, they were compressed using Digital Video Producer or Adobe Premiere to Microsoft AVI format using Cinepak, Intel Indeo, or Microsoft Video 1 compression. The quality of the video for the time (1994–1995) was fine; but in 1999 I decided that the videos needed to be recaptured at a higher resolution and frame rate. Also, since 1999 there has been an increase in the number of students using the MAC platform; therefore, all the new

recaptured videos had to be converted into Quicktime format so that the video clips could be viewed on both platforms. At the same time, the version of Authorware changed. Version 1 of this multimedia was authored using Authorware 2 while Version 5 was authored using Authorware 5. A new technical problem occurred with Version 4 of the multimedia. On certain Windows platforms (Windows NT, for example), the Quicktime videos would not run. Eventually, this technical problem was resolved by changing the programming in Authorware from a movie icon to a media type. Because of the financial constraints at SJSU, I was forced to allocate time to many programming issues. This time reduced the amount of time available for academic research and development projects.

Since the first version of the multimedia was published, there has been more research that has indicated the importance of good interface design in the context of learning (Maddux, Johnson, & Willis, 1997; Shneiderman, 1997). Brown (2000) called visual and design principles the forgotten partner in multimedia and Web development. As I learned the hard way through the student feedback to Versions 1 and 2, bad design and organization increases confusion in learners and causes them to “get lost.”

Most developers of multimedia assume that media-rich technologies help students form a deeper understanding of the material (Bayne & Land, 2000). The qualitative and quantitative evaluations I have conducted over the past few years show that this is almost always the case (Backer, 1995, 2000). The multimedia is “self-paced” and “empowering,” to quote two of the students surveyed, but it also behaves in unexpected ways. Students bring their existing worldviews and perspectives to their learning experience, and a multimedia learning environment does not give them the cues they are accustomed to from their professors. This is one reason that this course is a hybrid course rather than a multimedia-only course. A hybrid course balances multimedia instructions with discussion sessions with students. This structure allows the students to interact with each other and the instructor about the content and solves many problems inherent in self-paced instruction including high dropout rate, student lack of

focus, and difficulty in integrating the presented information into personal knowledge structures.

Most of the existing research shows that there is no significant difference in student achievement using multimedia as compared to “traditional instruction” (see Russell, 2000, for a review). Therefore, the debate should change to focus on increased access to education. Self-paced multimedia and Web-based courses give more access to more learners. The use of these CD-based modules has allowed students to have more flexibility in completing their GE requirements. In addition, it has allowed the department to serve a larger number of students with less faculty leading to higher FTEs and SFR. This is only one of two advanced GE courses in the College of Engineering at SJSU; therefore, this method of providing instruction provides more options and more flexibility to students in the completion of their GE requirements.

Beyond the effect on the curriculum at SJSU, this mode of delivery provides an opportunity for all STS courses. In this course, these multimedia modules seek to explain the nature and history of technology by using technology. The direct purpose is to provide in-depth course content for all instructors of this course. Indirectly, these modules give students the experience of using advanced technologies to learn about the nature of technology. Although the dichotomy is not directly stated in the multimedia materials, most students comment on the indirect messages about technology and their additional experiences, in this course, with technology as a learning medium.

As more universities consider adding STS courses to their curriculum, the delivery of these courses through multimedia can add depth to the story they are telling about the relation of technology to society. By using the Web and multimedia, student experiences can be enhanced and students can get a richer, more complex view of technology and its effects on our world.

Dr. Patricia Ryaby Backer is the chair of the Department of Aviation and Technology in the College of Engineering at San Jose State University. She is a member of Rho Chapter of Epsilon Pi Tau.

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An Evaluation of Internet-Based CAD Collaboration Tools

Shana Shiang-Fong Smith

During product design, over 80% of engineering changes are needed because designed parts cannot be manufactured or assembled (Stevens, 2001). Most of the design errors are due to lack of communication between the design team and manufacturing experts. To reduce communication problems and, thereby, increase product quality and reduce production costs, industry

has turned to concurrent and collaborative engineering methods (Prasad, 1996). However, in today's global market, designers and manufacturers are often geographically separated. Thus, designers, manufacturers, and suppliers need powerful communication tools so they can exchange design information effectively (Jones, Schwemin, Dorneich, & Dunmire, 2000).

The objectives of collaborative design include optimizing the mechanical function of a product, minimizing production or assembly costs, and ensuring that the product can be easily and economically operated and maintained. Effective collaboration tools can help resolve product design conflicts early in the design stage. As a result, product development, lead-time, and manufacturing cost can be greatly reduced. Thus, companies that use collaborative design tools realize many benefits. For example, by using a collaborative design tool to create its LBP-1210 laser printer, Canon was able to reduce design iterations, total cost, and lead-time (www.cocreate.com). Hewlett-Packard found that using a collaborative design tool helped immediately reduce overseas travel costs. Overall, using a collaborative design tool helped HP achieve a 135% return on investment (ROI) after one month and 240% after three months (www.cocreate.com).

Modern design teams often use CAD/CAM (computer aided design and computer aided manufacturing) tools to help facilitate their design process, from conceptual design stage to final production. Different companies or design partners may use different CAD/CAM tools. Since most existing CAD/CAM applications were designed to work in an isolated environment, inconsistent file formats often cause problems during information exchange.

Due to the now widespread use of the Internet, most companies now require CAD tools that support distributed collaborative design on the Internet (Lavana, Brglez, Reese, Konduri, & Chandrakasan, 2000). Such CAD tools should enable designers to share product models, as well as related data, from geographically distant locations (Shyamsundar & Gadh, 2001). However, integrated collaborative design capability over the Internet has not fully matured. For example, Potter (1997a) found that security and authentication are still major concerns when transferring CAD files over the Internet. Designers or companies need to protect intellectual property (Fornaro & Sanna, 2000).

This article determines the Internet-based collaborative design capabilities available in modern CAD tools, outlines the major problems

that still need to be addressed (e.g., version control, data translation and repair, and security and legitimacy issues), and recommends directions for future research.

Collaborative Design

According to Wang, Shen, Xie, Neelamkavil, & Pardasani (2001), if a product is designed through the collective and joint efforts of many designers, the design process used can be called collaborative design. The collaborative design process might include all design activities from concept creation through product definition, detailed design, manufacturing, assembly, maintenance, and even product retirement. Furthermore, some companies may enhance the collaborative design process by involving their customers, suppliers, and partners, over the Internet, throughout the product development and delivery process (Waltham, 2000).

Due to the often distributed nature of modern, Internet-based collaborative design processes, many different CAD tools may be used by a collaborative design team. When design teams use different CAD tools, problems often arise because different CAD tools still use different native file formats. For example, Autodesk Inventor generates part files in .ipt file format, and Pro/E generates part files in .prt file format. If design team members must share data stored in both file formats, a problem in model consistency might exist. Data communication problems due to using the Internet as a communication channel may also exist.

Therefore, collaborative CAD tools need a common, secure communication framework and protocol so that CAD files can be transferred safely and accurately. To meet the need, many CAD tools have recently added at least some of the following collaborative design capabilities: (a) real-time communication, (b) support for various CAD formats, (c) tools for publishing 2D/3D CAD designs on the Web, and (d) tools for manipulating CAD models outside the original CAD program.

Real-Time Communication

The Internet is probably the most convenient medium available for sharing CAD files in real time. CAD program vendors have begun to

use the existing power of the Internet and many existing Internet-based communication tools to improve the collaborative capabilities of their CAD programs. For example, to help designers share design data and models over the Internet, CAD vendors have begun to incorporate Internet-based conferencing and real-time 3-D model viewing tools directly into their products (Shyamsundar & Gadh, 2001). Autodesk integrates Windows NetMeeting into the latest version of Inventor. NetMeeting includes chat, whiteboard, program sharing, file transfer, remote desktop sharing, security, and video and audio conferencing. Thus, Autodesk Inventor users have online real-time communication capability available within the Inventor design environment. Table 1 provides a summary of collaborative functions available in Windows NetMeeting (Microsoft, 2001).

Windows NetMeeting remote desktop sharing allows a remote user to run a CAD program, which has been installed on a local computer, over the Internet. With remote desktop sharing, the remote user can use the local CAD program, running on the local machine, without having to install a copy of the CAD program at his or her remote site. As a result, the remote user can participate in a collaborative design session while at the same time reducing CAD program investment costs.

Support for Various CAD Formats

To share CAD files, collaborative design teams often must transfer CAD data from one CAD tool to another over the Internet. To deal with the issue, collaborative designers can store design files in a neutral file format. For example, if Company A in the U.S. uses AutoDesk Inventor while Company B in Japan uses Pro/E,

with current versions of Inventor and Pro/E, Company B could not read an Inventor .ipt file sent via the Internet by Company A. However, for successful collaborative design, Company A could save its CAD files in STEP (or another neutral file format) and then transfer the resulting STEP files to Company B via the Internet. Most modern CAD tools currently support several design file formats to improve their compatibility with other CAD tools. SolidWorks, for example, supports IGES, DWG, VRML, STL, VDA, SAT, DXF, and STEP file formats.

Tools for Publishing and Viewing 2D/3D CAD Designs on the Web

Distributed design teams need tools that address critical communication issues that are not addressed in stand-alone CAD tools. Often, for distributed design teams, customers, suppliers, vendors, and development partners who do not have CAD tools or CAD-tool expertise need to view and evaluate developing designs. To solve the problem, CAD vendors have begun to develop tools for publishing designs on the Web. For example, Parametric Technology Corporation (PTC) now offers a stand-alone tool called ProductView, which allows customers and other distributed design team members to preview designs on the Web, thus reducing product design and modification time and cost.

Tools for Manipulating CAD Models Outside the Original CAD System

Some CAD vendors offer stand-alone tools that provide more than just viewing capability. With tools for manipulating CAD models outside the original CAD environment, collaborative design team members without CAD tools or CAD-tool expertise can quickly and efficiently review design models. Manipulation tools allow

Table 1. Summary of Collaborative Functions in Windows NetMeeting.

FUNCTION	KEY FEATURES
Chat	Conducting multi-user real-time conversations using text
Whiteboard	Communicating in real time using graphics
Program sharing	Sharing programs during a conference
Remote desktop sharing	Operating a computer from a remote location
File transfer	Sending files in background mode during a NetMeeting conference
Security	Using security measures to protect privacy
Video and audio conferencing	Communicating on the Internet using video and audio

Table 2. Viewers Provided by CAD Companies.

Company Product	File Format Supported	Tools for Publishing CAD Designs on Web	Add Note/ Mark Up	URL
Solid Concepts SolidView	<ul style="list-style-type: none"> · Object (.obj) · SolidFile Exchange (.sfx) · SolidWorks (.sldprt, sldasm) · Stereolithography (.stl) · VRML (.wrl) 	N/A	✓	http://www.solidview.com
Parametric Tech. Corp. ProductView	<ul style="list-style-type: none"> · CADD · DWG · IDEAS · Pro/E · SW · UG 	✓	✓	http://www.ptc.com
EDS Solid Edge Web Publisher	<ul style="list-style-type: none"> · 3D IGES/2D IGES · VRML · DXF · DWG 	✓	Object	http://www.solid-edge.com/
SDRC Metaphase 3.2	<ul style="list-style-type: none"> · BMP · CGM · DWG · DXF · GIF · HPGL 	✓	Object	http://www.sdrc.com/metaphase/index.shtml
SolidWorks eDrawings Professional	<ul style="list-style-type: none"> · SolidWorks 2001 SP10 or higher · AutoCAD 2000, · AutoCAD R14.x · AutoCAD Mechanical R14.5 · SolidWorks design data · AutoCAD design data 	✓	✓	http://solidworks.com
SolidWorks SolidWorks Viewer	<ul style="list-style-type: none"> · IGES · DXF · DWG · STEP · VRML · Parasolid® · STL, ASCII, or binary format · VDAFS (VDA) · SAT (ACIS) 	N/A	N/A	http://solidworks.com
Autodesk Volo View	<ul style="list-style-type: none"> · DWG (AutoCAD-base) · DXF · DWF · Raster drawings · Inventor (.ipt .iam .idw) 	N/A	✓	http://usa.autodesk.com

users to translate, rotate, pan, zoom, and mark-up CAD models.

As an example, Autodesk offers Volo View Express, a free tool for viewing and manipulating Autodesk-format CAD files without Autodesk CAD tools installed. Volo View

Express allows users to open, view, make light-weight markups, and print CAD designs. Volo View Express supports Autodesk DWG, DXF, and DWF (ePlot and eView) file formats. With an additional downloadable Autodesk Inventor plug-in, VoloView allows users to view and print Autodesk Inventor part, assembly, and drawing

files without Inventor installed. Table 2 presents a list of tools offered by major CAD vendors for viewing and manipulating CAD files and the corresponding supported file formats.

Some third-party companies also provide CAD tools for viewing and modifying different types of CAD files online. For example, OneSpace Designer (from Ccreate Corp., www.ccreate.com) and IX SPeeD Suite (from ImpactXfot, www.impactxoft.com) allow users to load, view, inspect, and modify different types of CAD files during concurrent and collaborative design projects.

Issues in Collaborative Design

Update Issues

While working on a project, collaborative designers frequently make changes to parts that are being accessed at the same time by others working on the same project. One of the biggest problems with many Internet-based collaboration tools is that they do not have built-in multi-user version control capability. As a result, users can mistakenly use an older version of a file, rather than the latest version. Drawings may be sent out and considered final when they actually are not. Therefore, efficient collaborative design tools must support inconsistency prevention and detection (Despres, Piloty, & Schellin, 1993).

Many existing single-user CAD tools allow the user to set model version numbers to help track any design changes made during the product development process. Each time a model's content is modified and saved in a working file, the tool assigns a new version number to the working file. A new version of the model is created each time the file is saved. Usually, the CAD tool, after the number of saved versions reaches a maximum limit (for example, 10 in AutoDesk Inventor), discards the oldest version of the model whenever a new version is saved. The user can then open, view, and modify any saved version of the model.

To allow multiple users to access the same files, AutoDesk added a multi-user option to Inventor. Users must select the multi-user option before starting work on a collaborative project. With the multi-user option selected, all members of a group can access the same project files.

AutoDesk Inventor also enables safeguards when several users are editing the same files.

After a user activates the file reservation system and warning functions inside AutoDesk Inventor, Inventor automatically reserves any new files the user creates for that user. If another person attempts to edit a reserved file, a warning message alerts the person for whom the file is reserved.

Data Translation and Repair Issues

In a collaborative design environment, team members might use different design software when working on a model. A major problem with using various heterogeneous CAD programs is lack of interoperability between the systems (NIST). Data translation issues cause many concerns (Potter, 1997b). For example, a designer could receive three parts from three different design team members in three different file formats, e.g., an Inventor (.ipt), a Pro/E (.prt), and a STEP (.stp) file. To combine the three parts into a single design, the designer would need to translate all the files into a format supported by his or her CAD tool and then import the parts into his or her CAD tool.

The design team could eliminate both the problem due to mismatched file formats and the time required for data translation by saving and transferring CAD part designs in a neutral file format (e.g., STEP or IGES). However, saving and transferring CAD files in neutral file format does not remove problems with internal data consistency.

Since different CAD tools often use different internal accuracy levels, a target system may not be able to recognize an imported model as a solid body after data conversion. Errors such as cracks, degeneracy, duplication, holes, and overlaps usually occur in the models when users import them from other CAD tools (Barequet & Kumar, 1997). Upgrading a low-resolution solid model into a high-resolution solid model can be a difficult problem. Often, users need an expensive repair and healing tool to make the model usable (Farrell, 1999). In addition, state-of-the-art healing tools often cannot successfully repair imported CAD models.

A 1999 study by RTI International (<http://www.rti.org>) estimated that imperfect interoperability imposes costs of at least \$1 billion per year on the U.S. automotive supply chain alone; other industries face similar difficulties.

Internet Security and Legitimacy Issues

With the explosive growth in Internet use, network security has become an inevitable concern for a growing number of organizations (Yu & Le, 2000). Since CAD files often serve as legal documents, cautious CAD users may not be willing to use any tools that create a risk of exposing their designs to outsiders (Hauck & Knol, 1998). Users often express concerns about having their files stolen during transmission (Farrell, 2000), and many people are not totally comfortable when sending information across the Internet. Users often believe that if a file is sent over the Internet, someone might steal or modify the file. Indeed, some surveys already indicate that many companies are not willing to use the Internet to transfer their CAD data (Potter, 1997a). Thus, in the future, collaborative CAD tools must offer more capabilities for securing files and encrypting models.

Speed Issues

Speed is another issue facing Internet-based CAD researchers and developers. Today's fast Internet connections allow almost immediate response for low-density data. However, CAD data generally contains a large amount of information in every file. As a result, current collaborative CAD tool users need to, but currently cannot, see design animations in real time. Without even higher-speed Internet connections, collaborative CAD users might find their modeling experiences very frustrating. Therefore, in order to manipulate CAD models in real time, more advanced communication hardware and software are required.

Conclusion

Growing Internet use has led to Internet-based collaboration functions in major CAD packages. With currently available capabilities, users can exchange and share CAD files in real

time using Internet-based conferencing utilities. Furthermore, some major CAD vendors now offer tools for publishing 2D/3D CAD designs on the Web and for viewing and manipulating CAD models outside the original CAD program. With CAD model Web publishing, viewing, and manipulating tools, collaborative design team members can communicate effectively, even from different geographical locations, without purchasing or installing separate copies of the CAD tool(s) used. Most major CAD tools now offer support for saving and importing CAD files in several different file formats (in particular, neutral file formats such as STEP and IGES), which is a critical feature for collaborative design. With neutral file format capability, collaborative CAD file exchange over the Internet is becoming easier.

Remaining problems facing collaborative CAD tool researchers and developers include technical difficulties related to data translation and file security. Data translation often leaves cracks, degeneracy, duplications, holes, and overlaps in models. Security issues on the Internet leave many companies concerned that their designs might be lost, stolen, or modified when transferred over the Internet.

Improved Internet-based collaborative CAD tools can enhance communication in the CAD/CAM industry. As a result, collaborative CAD tools can also reduce product development and manufacturing costs. As Internet use becomes more widespread, Internet and computer networking capabilities will continue to improve. However, capabilities in collaborative tools for CAD/CAM design need to improve as well. A review of current collaborative CAD capabilities shows that although some capabilities exist, further research and development is needed, particularly in the areas of data repair, data integrity, and data security.

Dr. Shana Shiang-Fong Smith is an Assistant Professor in the Department of Industrial Education and Technology at Iowa State University.

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A Model to Integrate Online Teaching and Learning Tools Into the Classroom

Klaus Schmidt

With the evolution of the World Wide Web, online teaching and learning has gained a tremendous amount of popularity. New Web teaching and learning tools are created at a fast pace to help better address the multitude of teaching and learning styles. Liu and Thompson (1999) found that faculty members are more likely to use a wider variety of educational technologies when exposed to online teaching and learning tools and thus teach to a broader array of learning styles. The increasing diversity of learning strategies is a growing challenge for teachers. One way to address this challenge is to incorporate online learning tools into the traditional classroom. Such a combination may benefit both students and teachers if those tools provide quality teaching and learning opportunities and outcomes. However, little research exists on how learning environments can be created that successfully combine online teaching and learning with traditional classroom environments to enhance student learning.

This article introduces a model that addresses how an effective combination of online and traditional classroom teaching can be obtained. The article shows how learning outcomes and preferences as well as the awareness of student characteristics and student feedback such as the perception of classroom environment can be used to enhance the quality of a combined learning environment.

Students' perceptions of the classroom environment are indicators of successful learning. Cheung (1998) stated that student feedback is essential for improving the academic quality of online learning. Sherry, Fulford, and Zhang (1998) discussed the positive relationships between students' satisfaction with instruction and their subsequent success in a course. Fitzelle and Trochim (1996) found that enjoyment and control of pace were significant factors in student success with online instruction. It follows that assessing students' perceptions of their preferred instructional environment is an integral

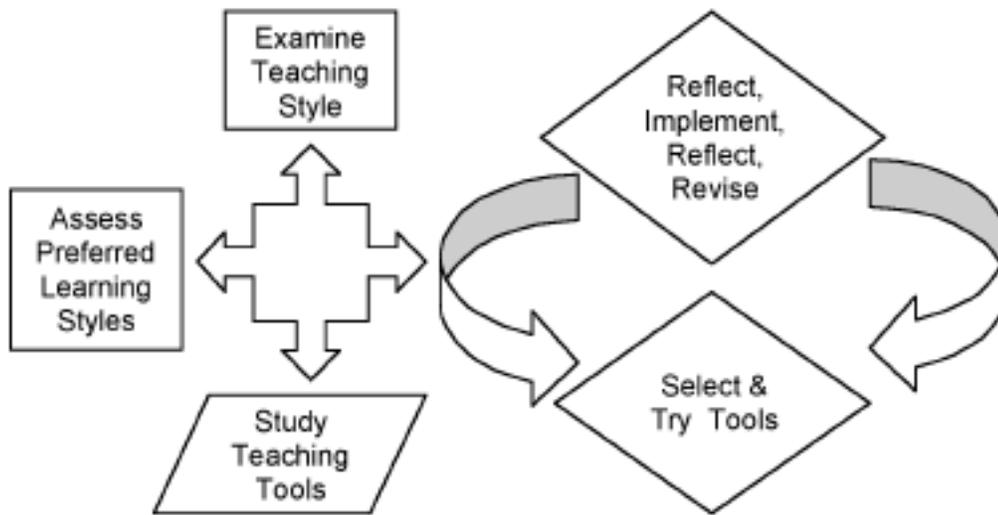
role in developing instruction that motivates students to achieve desired learning outcomes.

When considering the replacement of one teaching method or tool with another, it should be assured that the quality of the learning experience is not diminished. It is important to not simply accommodate students' preferred learning styles, but also to expand on students' learning strategies by exposing them to other viable and interesting ways of learning. The combination of online learning with traditional classroom instruction could diversify teaching and learning alike, and as a bonus enhance technological literacy of both the faculty and students.

Literature identifies various models of combining online learning with traditional classroom learning and assessing the quality of such combinations (Eberling, 2000; Grasha & Yangerber-Hicks, 2000; Simon, 2000; Spoon & Schell, 1998). In general, students participating in entire classes online have demonstrated no significant differences in learning when compared to students taking classes in traditional classroom settings (Benbunan-Fich & Hiltz, 1999; Johnson, Aragon, Shaik, & Palma-Rivas, 2001; LaRose, Gregg, & Eastin, 1998; Swan & Jackman, 2000). Wheeler and Jarboe (2001) added that a combination of online and traditional classroom instruction has become the most popular way to use Internet teaching and learning tools. LaRose et al. (1998) discussed the potential of online learning to enhance individual student learning.

Furthermore, Ester (1994-95), Goldberg (1997), and Wheeler and Jarboe (2001) found that students with access to both traditional lectures and an online environment fared better academically than students instructed either entirely in the traditional classroom or entirely via the Internet. Sanders and Mirrison-Shetlar (2001) found that including Web-based components in an otherwise traditional college level biology course increased student learning and enhanced problem-solving skills.

Figure 1. Model for incorporating online teaching tools.



The model presented in Figure 1 suggests five considerations that may be useful when creating a quality mix of online and traditional classroom teaching and learning. The steps Examine Teaching Style, Assess Preferred Learning Styles, and Study Teaching Tools can occur simultaneously or in any order. It is recommended that the instructor fully understands and completes the first three steps prior to moving on to Select and Try Tools and then Reflect, Implement, Reflect, and Revise. The entire process is ongoing and iterative. Each step is explained in more detail on the following pages.

Step 1: Examine Your Teaching Style

Assessing the preferred personal teaching style is one of the first steps a teacher should take prior to selecting and implementing online teaching and learning tools. Understanding one's personal teaching style can help to determine which traditional course components can be best enhanced with online teaching and learning technology and which tools will most comfortably match the teacher's personal teaching style. Preferred teaching style may be identified through careful personal reflection or through use of any of a number of available instruction/teaching styles inventories. Two common instruments designed to assess teaching styles are the Canfield Instructional Styles Inventory (ISI) and Grasha's 5 Teaching Styles Inventory. The ISI categorizes teaching styles along two basic dyads: social or independent, and conceptual or applied. For example, if the

identified teaching style is social, a teacher wishing to incorporate online instructional components might consider which available online tools could effectively replace or supplement traditional social instructional techniques such as group discussion and team activities. Online chat rooms or discussion tools designed to create a social learning environment and a sense of community between teacher and students might be helpful. Conversely, if after consideration it is determined that the existing online tools do not meet these particular needs, the teacher might refrain from using online chat rooms or discussion tools to supplement classroom teaching in this instance.

Grasha's 5 Teaching Styles Inventory describes teaching styles within five major categories: facilitator, formal authority, expert, personal model, and delegator. If a teaching style is predominantly the role of a facilitator, the teacher should identify tools that help to support the facilitator role¹. On the other hand, if the teaching style is identified as expert, the teacher might include video or audio enhanced presentations and lectures.

With respect to identifying the teaching style, this model does not give preference to any particular teaching style or teaching styles assessment tool. The teacher is free to choose whichever approach he or she is comfortable with. It might even be helpful to choose multiple instruments or approaches as each addresses different

elements of teaching styles. Nevertheless, being aware of teaching styles alone does not guarantee that student learning takes place. In order to facilitate student learning, a teacher also needs to consider and be aware of his or her students' preferred learning styles.

Step 2: Assess Your Students' Preferred Learning Styles

Understanding how students learn is imperative. This is especially true when considering the incorporation of a greater variety of teaching tools, as is the case when combining online and traditional classroom teaching. Several studies (Ayersman & Reed, 1995-96; Ester, 1994-95; Ross, Drysdale, & Schultz, 2001) have found relationships between learning styles and student perceptions of and/or learning successes with online instructional components. In a study designed to decrease the levels of students' computer anxiety, the highest level of computer anxiety was demonstrated by students identified as divergers and the lowest levels were demonstrated by students identified as convergers using the Kolb Learning Styles Indicator (Ayersman & Reed, 1995-96).

Literature discusses a wide array of instruments to assess learning styles (Crowe, 2000; Dunn & Griggs, 2000; Miller, 2001). Four commonly used instruments are the Myers-Briggs Type Indicator (MBTI), the Kolb Learning Style Indicator, the Canfield Learning Styles Instrument (LSI), and the Dunn, Dunn, and Price Productivity Environmental Preference Survey (PEP). While the MBTI focuses on the four dimensions of extroversion versus introversion, sensing versus intuition, thinking versus feeling, and judging versus perceptive, the Kolb Learning Style Indicator collects student information on four scales including preference for concrete experiencing, abstract conceptualization, reflective observation, and active experimentation. The Canfield LSI places learning styles into categories such as social, independent, applied, and conceptual. The PEP profiles student learning preferences in such learning related factors as noise and light levels, temperature, motivation, persistence, structure, authority, senses, time of day, etc. However, it might not always be necessary to formally assess students' learning styles.

Information about students' preferred learning styles may be collected informally through discussions with students or observations of students in the classroom.

Once a teacher has identified his or her teaching style and is able to identify students' learning styles, an appropriate mix of online and traditional teaching and learning tools may be identified. For example, if the LSI is used and students identify themselves as social learners, it will be beneficial to incorporate online and traditional teaching and learning tools such as online chat rooms or discussion tools. If the social learning style cannot be adequately met using only online tools for a particular course, the instructor might decide to emphasize the social learning style more heavily using traditional classroom tools or a combination of traditional and online tools. If a teacher's teaching style is learner centered but the students prefer the teacher centered environment, students may obtain lower learning outcomes due to a mismatch of teaching and learning styles. In such a scenario, the teacher could identify and apply or supplement learner-centered instruction with tools that enhance a teacher-centered learning style. This approach would not only widen students' learning strategies but also a teacher's portfolio of teaching techniques. Matching the teaching style with the learning style of students may not solve all issues related to learning in the college environment, but it could help to identify Internet technologies for a better integration of traditional and online teaching and learning tools and thus address a wider variety of learning styles.

Step 3: Study Online and Traditional Teaching and Learning Tools

A good command of both online and traditional teaching and learning tools is important for the development of a successful combination of those tools. The following section focuses on online teaching and learning tools and on how these tools can be incorporated into the classroom.

A broad array of online teaching and learning tools are available. Almost all aspects of classroom teaching can be enhanced or replaced with online technology in some contexts. To obtain a broader overview of enhanc-

ing the classroom with Web technology, the classroom environment can be categorized into four components: administration, assessment, content delivery, and community (Schmidt, 2002b). Various online tools exist to help in these components. Appropriate selection of online tools will depend not only on the instructional content but also on the quality of the available tools and the level of technical ability of teacher and students. For example, if both teacher and students have mastered a specific content delivery tool, it can be beneficial to deliver content online rather than in the classroom. Similarly, if the teacher has found ways to meaningfully incorporate synchronous communication tools (such as chat), students might also benefit from the added community component. The following discussion of each component will demonstrate how Web tools could be incorporated to meet certain aspects of a course to enhance student learning.

The administrative component is the foundation for the organization of a course and allows a teacher to spend more class time interacting creatively with students rather than on mundane activities. For example, activities such as turning in or returning graded assignments during class time can be replaced with Internet technology. The time “gained” during class can then be used for other higher order thinking and learning activities. The assessment component addresses student performance. Using online assessment tools such as online quizzes to provide instant feedback and repeated testing opportunities for practicing purposes may help students learn the subject matter more thoroughly. This method also leads to more class time for student-student and student-teacher interaction (Schmidt, 2002b). Sanders and Morrison-Shetlar (2001) found that students were comfortable tracking quizzes and tests online and liked having online access to their individual grades to assess how well they were doing in the coursework.

The content delivery component focuses on the communication of course content and learning activities. Research shows that a significant amount of learning can take place outside the traditional classroom if students have access to and are motivated to study the material at their

own pace. Ryan, Hodson Carlton, and Ali (1998) found that students enjoy using the Internet for the structured presentation of course material and prefer traditional class time to be used for informal interaction and the development of advanced thinking skills.

The community component addresses development of a community of learners, the sense of community among students and between teachers and students. Online teaching and learning tools can help to create a community of learners that is no longer limited to just one teacher and his or her students in the classroom. Depending on teaching and learning styles, a community (including experts and experienced practitioners) from outside the classroom can be introduced to the classroom and benefit both the teacher and the learners. Numerous academic and educational online communities can be accessed and included in the learning process². It takes careful planning to help students deal effectively with the many challenges of online interaction and community building. Sanders and Morrison-Shetlar (2001) reported that students had mixed perceptions about the value of being required to access and participate in chat rooms and bulletin boards as the primary community components of classes. Students generally preferred asynchronous tools to synchronous tools.

Once the first three steps are completed, the challenge is to balance the identified preferred learning and teaching styles against the advantages and disadvantages of available online instructional technology. This should be viewed as a problem-solving challenge with many potentially correct solutions.

Step 4: Select Online Teaching and Learning Tools

Considering the adoption of online instructional delivery methods may present opportunities to achieve learning objectives beyond the basic acquisition of content knowledge and/or skills such as enhancing students’ levels of computer literacy. However, unless very carefully designed and implemented, different forms of instructional tools may favor students with some learning styles and technical expertise at the expense of others. Ross et al. (2001) found that

sequential learners studying computer applications using some computer-based instructional tools performed significantly better in acquisition of both skills and knowledge than did students identified as random learners. Students identified as abstract sequential in learning style performed significantly better in this study than students with any other style. Students in this study who failed the courses or withdrew were overwhelmingly identified as abstract random in style. Similarly, in another study Ross and Schulz (1999) reported that there was significant interaction between learning styles and learning outcomes. In this study students identified as abstract sequential averaged an 18% gain in learning, students identified as concrete sequential and concrete random averaged a 10% learning gain, while students identified as abstract random averaged a 10% decrease in learning. When exploring the relationships between learning styles and learning outcomes in a course instructed using computer-based instructional tools, Davidson and Savenye (1992) identified positive significant correlations between learning outcomes and abstract sequential learning styles and negative significant correlations between learning outcomes and abstract random learning styles.

Khalili and Shashaani (1994) found in their meta-analysis of computer applications for instruction that different types of computer-based instructional tools have different effects on students' learning outcomes. Carefully selected and/or designed online delivery methods may enhance learning outcomes in general but also students' levels of computer literacy and sense of efficacy when using computers as learning tools. In an age of burgeoning adoption of e-mail, e-meetings, and e-teams in the workplace, these expanded computer-based experiences may help to better emulate the new workplace. Additionally, if content is delivered in parallel forms both through traditional means and through using online tools such that students have the opportunities to learn in their preferred modes, some students may become more aware of their own cognitive processes and begin to expand the range of learning environments that they will happily work in.

The two primary indicators of the quality of

instructional tools implemented into the classroom are students' perception of the learning environment and students' learning outcomes. Using student feedback and the results from analyses of the learning outcomes enables a teacher to make decisions on what online learning activities best contribute to student learning and what framework best addresses pedagogical and technological issues. In addition, the student feedback helps to decide which online components are less liked and do not result in a positive learning experience.

One tool to help assess the effectiveness of the online tools and the quality of the combined learning environments is classroom action research. Classroom action research helps a teacher to try out new online tools, implement those that are successful, and gather student feedback, reflect, and revise to further improve and develop the course (Schmidt, 2002a).

Step 5: Reflect, Implement, Reflect, and Revise

Because this model suggests an iterative and continuous process, it will be imperative to continuously reflect, implement, further reflect on the outcomes of the implementation, and revise again the mix of online and traditional teaching and learning tools. Due to the changing nature of the online environment, only a dynamic approach to teaching and learning will maximize success.

Students' learning style preferences impact upon the quality of their attitude toward a particular instructional tool, but an instructor's consciousness of the importance of learning style preferences may help him or her to adapt tools for teaching that address the learning needs of students with multiple learning style preferences. Ross et al. (2001) recommended that one important alternative consideration when designing online instructional tools is to teach students to use strategies that will succeed in learning situations that do not favor their preferred learning style.

Conclusions

As mentioned previously, the model suggested in this article is iterative in nature. It is not intended to be a linear process leading to

selection of the best combination of instructional methods because the best combination of methods is constantly in flux. This model is rather intended to encourage continuous experimentation with both new and traditional instructional tools and methods to achieve ongoing improvement based on trial assessment and reflection of outcomes. The goal here is to attempt to improve student learning while also promoting enhanced student satisfaction levels with the learning experiences and environment.

Because this model is dynamic, it is expected that teachers will need to be open to continuous change. Students' learning styles may vary widely from student to student, new online teaching and learning tools will continue to be developed, and an increased awareness of one's teaching style will lead to modifications within the composition of online tools and classroom interaction. Only by considering these variables can a teacher continue to address students' changing learning needs in a creative, flexible, and dynamic teaching and learning environment.

Finding the right combination of online and traditional teaching and learning tools to meet

the broad array of learning styles remains one of the greatest challenges in today's teaching environment. Considering teaching and learning styles when incorporating online teaching and learning tools can help a teacher to better address student learning needs. Student learning is strongly impacted by the teacher's ability to communicate the subject matter. Creating a successful learning environment therefore heavily depends on the creativity of the teacher. It will be important to decide which course components can be enhanced most effectively via the Internet and which can be done more effectively in the traditional classroom. Only a continuous assessment of learning and teaching styles and Internet tools will help to appropriately address these issues and best meet student learning needs. We believe that in a world where lifelong learning is essential for students' long-term success, only students who experience learning in positive learning environments are likely to continue their journeys toward becoming successful lifelong learners.

Dr. Klaus Schmidt is an assistant professor in the Department of Technology at Illinois State University.

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Notes

- ¹ The Grasha 5 Teaching Styles Inventory can be accessed online at <http://frc.indstate.edu/tstyles3.html>.
- ² Visit <http://www.webct.com/wyw> or <http://www.akiva.com/solutions/community.cfm>



Through interaction with digital technologies for work, play, and communication, our pattern for intellectual development is being altered. The multiple intelligences theoretical framework developed by Gardner (1983) is easily employed to provide evidence that yet another intelligence, digital intelligence, has emerged. In our postmodern pluralistic global culture, the multiple intelligences theory has enjoyed success and has impacted teaching practice. By acknowledging the existence of a new digital intelligence and all of the implications this acknowledgement may create for education and communication, we increase our ability to develop effective strategies to accommodate this new intellectual style.

Gardner (1999) encountered evidence that did not easily fit in his original model of multiple intelligences and he supposes more intelligence categories to accommodate his observations. Gardner submitted two additional distinct intelligences: moral intelligence and spiritual intelligence. He also pondered that besides these two new vessels for containment even more information has emerged that surrounds the intellectual virtuosos he described as “symbol analysts” and “masters of change.” Could these observed but unclassified characteristics be the indication of an emerging intelligence that is being fostered by human interaction with digital technologies?

Knowledge, Ways of Knowing, and Intelligence

Information is a fluid that often takes on no form until a pattern is discovered that appears to take into consideration that many possibilities for assemblage exist, but settles on the most accommodating. As with most strong models and theories, the multiple intelligences theory has defined rules for organization of information that will accommodate new evidence in such a way that will further extend the organization and therefore substantiate existing understanding and work to create new knowledge. To facilitate a discussion of intelligence, one must possess an understanding of the relationship

between knowledge, modes of knowing, and intelligence. While each has a distinct definition, all exist in an interactive relationship.

Knowledge

Knowledge can very broadly be defined as what we know or believe to exist. Many conceptions of the organization of knowledge exist. “The task of demarcating kinds of knowledge is not unlike that of demarcating different territories on a map. As there are different kinds of maps of territory, so there are different kinds of maps of knowledge” (Schrag, 1992, p. 268). Machlup (1980), in the first volume of his proposed eight volume set entitled *Knowledge: Its Creation, Distribution, and Economic Significance*, created a classification for the types of knowledge by grouping what we are able to know into discrete categories such as mundane knowledge, scientific knowledge, humanistic knowledge, social-science knowledge, and artistic knowledge. A discussion of the many knowledge classification systems is beyond the scope of this article. Machlup’s classification is mentioned to illustrate one conception of knowledge as “what we know.”

Ways of Knowing

The modes of knowing or ways of knowing endeavor to describe the human process of internalizing knowledge. Eisner (1985), in his preface to *Learning and Teaching the Ways of Knowing*, described his editing assumptions:

Since contexts change, the capacities of mind themselves alter. The roads to knowledge are many. Knowledge is not defined by any single system of thought, but is diverse. What people know is expressed in the cultural resources present in all cultures. (p. 3)

Included as topics in this collection of modes of knowing are aesthetic, scientific, interpersonal, narrative, formal, practical, and spiritual ways of knowing.

The question of what knowledge is most worthy of knowing and by which mode of

knowing this knowledge is to be internalized is often cultural but is ultimately a personal decision. Knowledge and the ways of knowing work together to create intelligence.

Intelligence

Intelligence, as defined by Gardner (1993), is “the ability to solve problems, or fashion products, that are valued in one or more cultural or community settings” (p. 7). More simply put, it is the ability of individuals to use knowledge in a personal way to successfully interact with their environment. Gardner’s definition of intelligence differs somewhat from the widely held notion that intelligence is a direct measure of knowledge. Intelligence becomes a measure of enculturation, combining knowledge and the ways of knowing with the ability to interact effectively in a cultural or community setting.

Multiple Intelligences Theory

In his original multiple intelligences classification system, Gardner (1993) defined the criteria for distinction of intelligence classes. He stated, “Each intelligence must have an identifiable core operation or set of operations. As a neurally based computational system, each intelligence is activated or ‘triggered’ by certain kinds of internally or externally presented information” (p. 16). An additional criterion was described that “an intelligence must also be susceptible to encoding in a symbol system—a culturally contrived systems of meaning, which captures and conveys important forms of information” (p. 16). Gardner contended that intelligence takes on seven domains or modes of operation. He likened intelligence to talent and outlined the following seven domains in which talent or intelligence functions: musical, bodily-kinesthetic, verbal-linguistic, interpersonal, intrapersonal, spatial, and logical-mathematical. Gardner contended that these seven intelligences reflect the way the nervous system has evolved over the millennia to yield certain discrete kinds of intelligence. He claimed that it is irrelevant whether intelligence is either inborn or learned.

Digital Intelligence — The Argument for an Additional Intelligence

No one contends that any of the original seven intelligences or the two new intelligences used for Gardner’s (1983) theoretical framework

are invalid; it is merely observed that yet another intelligence has emerged. A different intelligence, resulting from human interaction with digital computers, exists.

Classification systems are constructed around the developer’s beliefs of what knowledge is worthy of transmission. Gardner (1983) may not have held digital knowledge in the same esteem as other knowledge structures when creating his framework. As with all strong models, he did allow for the development of other intelligences. In the epilogue of *Multiple Intelligences: Theory in Practice*, Gardner (1993) foresaw “the mental landscape [of the future] might be reconfigured in light of accumulated knowledge. I have every reason to believe that the map would be drawn in a somewhat different way” (p. 250). Possibly the future is not as distant as the year 2013 that Gardner chose for prediction. In 1965, it was estimated that knowledge doubled every five years. By the year 2003, it is predicted that knowledge will double every two months. Gardner may have figured time on the 1965 scale.

Gardner’s (1993) own definition of intelligence as “the ability to solve problems or fashion products that are of consequence in a particular cultural setting or community” (p. 15) sets criteria allowing for the emergence of a digital intelligence. Our society is increasingly becoming McLuhan’s (1964) “global village.” Digital technologies have truly become an extension of man and the external neural network McLuhan described is under construction. This new intelligence is a response to the cultural change brought about by digital technologies and takes into account the skills and talents possessed by the “symbol analysts” and “masters of change” recently recognized in Gardner’s (1999) latest book. Through the development and infusion of digital technology, communication methods are rapidly expanding and taking on new forms. These technological advancements have allowed fluency across all cultures and at the same time have rapidly increased our ability for information gathering, storage, and retrieval. A new intelligence has begun to emerge—one that allows us to effectively fashion products that are of consequence in this new cultural and community setting.

Artists often describe their ability to create art as if the information or knowledge about their particular art exists in a multidimensional state in their environment. Their talent lies in their ability to decode this information and transfer it into a medium that others can more easily appreciate. This is the artists' own description of the talent or intelligence that Gardner (1983) termed musical intelligence. We have developed this type of phenomenon with information of all descriptions. We have moved it into multidimensional digital space. Information is no longer arranged in linear fashion but is now object oriented and often clustered. Because of the new functions provided through digital technologies, information/knowledge may be personally arranged and rearranged. It could be said that those with the ability to understand and interact with this digital information to arrange, manipulate, and display it according to their perceptions possess yet another intelligence—an intelligence made up of components of the other intelligences, just as musical or spatial intelligence is described by Gardner to exist. As Gardner (1999) described, there exist individual virtuosos with the characteristics of symbol analyst and master of change. Those possessing this talent could be termed digitally intelligent.

Continuing with Gardner's (1993) criteria of universality and symbol encoding system to define the existence of a discrete intelligence, there is little question of the universality of digital media across cultures. The development of computer icons used for communication within a digital environment satisfies the criterion of encoding in a symbol system. When using Gardner's own criterion for intelligence classification, digital intelligence logically exists.

Postman (1992) wrote of "the surrender of culture to technology." Slouka (1995) told with caustic humor of his initiation into cyberspace: "What I discovered, obscured by the 'noise' of the Internet, was arguably the biggest subculture in recorded history, a virtual electronic nation" (p. 43). Papert (1993) described how computers changed the fabric of my own work. What struck me most forcibly [about computers] was that certain problems

that had been abstract and hard to grasp became concrete and transparent, and certain projects that had seemed interesting but too complex to undertake became manageable. (p. 13)

These references are being made about the ability to fashion products in the form of information/communication that are of consequence in a digital culture or community.

Current literature has found a link between the multiple intelligences theory and technology. Articles outlining the uses of technology to address multimodal learning are increasing in popularity. These articles often describe the flexibility of digital technologies and prescribe specific uses of digital media to facilitate development of each of Gardner's (1993) seven currently described intelligences. Gardner described how learning to program a computer might involve multiple intelligences:

Logical-mathematical intelligence seems central, because programming depends upon the deployment of strict procedures to solve a problem or attain a goal in a finite number of steps. Linguistic intelligence is also relevant, at least as long as manual and computer languages make use of ordinary language...an individual with a strong musical bent might best be introduced to programming by attempting to program a simple musical piece (or master a program that composes). An individual with strong spatial abilities might be initiated through some form of computer graphics—and might be aided in the task of programming through the use of a flowchart or some other spatial diagram. Personal intelligences can play important roles. The extensive planning of steps and goals carried out by the individual engaged in programming relies on intrapersonal forms of thinking, even as the cooperation needed for carrying a complex task or for learning new computational skills may rely on an individual's ability to work with a team. Kinesthetic intelligence may play a role in working

with the computer itself, by facilitating skill at the terminal. (p. 390)

Gardner's description of the interaction of all of the seven intelligences with technology could lead one to conclude that digital intelligence has evolved as a meta-intelligence—one that is composed of many of the constituent intelligences.

A change in world culture caused by digital technology is occurring. Changes in communication style, life style, economic practice, and the way we think have been caused by digital technology. Our "ability to solve problems or fashion products that are of consequence in a particular cultural setting or community" (Gardner, 1993, p. 15) is directly related to our ability to interact with this emerging digital environment.

Turkle (1995) wrote:

The computer offers us both new model of mind and a new medium on which to project our ideas and fantasies...a nascent culture of simulation is affecting our ideas about mind, body, self and machine. (pp. 9-10)

The lessons of computing today have little to do with calculation and rules; instead they concern simulation, navigation, and interaction....The computer culture's center of gravity has shifted decisively to people who do not think of themselves as programmers. (p. 19)

We are moving from a modernist culture of calculation toward a postmodernist culture of simulation.... Mainstream computer researchers no longer aspire to program intelligence into computers but expect intelligence to emerge from the interactions of small subprograms. If these emergent simulations are "opaque," this is not necessarily a problem...our brains are opaque to us, but this has never prevented them from functioning perfectly well as minds. (pp. 19-20)

Healy (1990) contended changing lifestyles may be altering children's brains in

subtle but critical ways and spoke of the development of a new intellectual style. When discussing digital technology, she wrote that "subtle shifts in what the human brain is required to do will eventually cause it to modify itself for new uses" (p. 332). Her concern with this topic caused her to inquire of Dr. Jerome Bruner his opinion of changing brains in a technological age. His reply:

The only thing I can say with some degree of certainty is that the evolution of human brain function has changed principally in response to the linkage between human beings and different tool systems. It would seem as if technology and its development leads to a new basis of selection...surely there must be a variety of changes in progress that resulted from writing systems, even though writing systems were introduced only a short time ago as far as we reckon on evolutionary time. And now, of course, we have computers and video systems, and how long before the selection pattern changes as a result of these? (Healy, 1990, p. 334)

McLuhan (1964) told us "the medium is the message/message" (p. 2), meaning our intelligences are shaped by the communication media we employ. Negroponte (1995) believed that our digital acumen has evolved to a point where "the medium is not the message in a digital world. It is an embodiment of it. A message might have several embodiments automatically derivable from the same data" (p. 71). He contended that our accessibility to knowledge in the form of information is becoming seemingly limitless, and with this accessibility comes the ability for us to interpret that knowledge in whichever way our intelligences need it to be interpreted.

A digital intelligence is emerging. It has rooted itself in our conceptions of knowledge and has become integrated into our ways of knowing. Intellectual skills have begun to depend upon our ability to interact in a digital environment. It is true that technology is a tool, but these digital tools have changed world culture. "An artifact pushed far enough tends to

reincorporate the user” (McLuhan & Powers, 1989, p. 3). Considerable uncertainty surrounds the impact that possession of this emerging digital intelligence will have on the future structure of our society. Such things as individual self-concept, teaching and learning practices, and organizational authority are but a few of the areas that have begun to feel the impact. The recognition and incorporation of this new intel-

ligence as a category in the multiple intelligences theory would serve to widen the inquiry into responsive teaching and learning.

Dr. Nan B. Adams is an assistant professor in the Department of Educational Leadership and Technology at Southeastern Louisiana University.

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An In-Process Surface Roughness Recognition System in End Milling Operations

Lieh-Dai Yang and Joseph C. Chen

Computer numerical control (CNC) machines have been very successful in increasing productivity, repeatability, and accuracy of parts, reducing production and labor costs, and lowering operator skill in manufacturing industry (Degarmo, Black, & Kohser, 1999). In order to assure machined part quality, the operator traditionally inspects the machined parts by stopping the machine, cleaning the workpiece, and removing the workpiece from the machine table. Then, the inspection instruments are able to measure quality characteristics, such as surface roughness, inspected by a stylus profilometer. It is very time and cost consuming to conduct a quality inspection of machined parts in this manner. If there were an in-process inspection technique that could be used to measure quality characteristics of machined parts in a real-time manner without stopping the machine and removing the workpiece, productivity could be increased and time and money could be saved.

To develop an in-process quality control system, a sensor technique and a decision-making algorithm need to be applied during machining operations. Several sensor techniques have been used in the in-process prediction of quality characteristics in machining operations. For example, an accelerometer sensor was used to monitor the vibration of milling operations to develop an on-line surface roughness measuring technique in end milling operations (Chen & Lou, 1999; Jang, Choi, Kim, & Hsiao, 1996). An ultrasonic sensor was used to develop an in-process measurement of ultrasonic beams from surface roughness in milling operations (Coker & Shin, 1996). An acoustic emission sensor was used to monitor transient stress waves to estimate surface roughness in grinding (Susic & Grabec, 1995). A dynamometer sensor can be used to generate cutting forces in machining; however, the effects of surface roughness caused by cutting forces have not been taken into consideration in past research. Lee and Lin (2000) indicated that cutting forces have the most significant impact on the quality of machined parts

in end milling operations. Therefore, cutting force is to be included in developing cutting parameters affecting a surface roughness recognition system in end milling operations.

After a sensor has been selected to monitor machining operations, a proper decision-making algorithm needs to be developed to establish a recognition system by using the data collected from the sensor. Many decision-making algorithms have been developed throughout the past decade. For example, fuzzy logic, neural network, and neural fuzzy systems have been applied in the in-process surface roughness recognition (IPSRR) system (Chen & Savage, 2001; Coker & Shin, 1996; Chen & Lou, 1999, 2000; Susic & Grabec, 1995; Tsai, Chen, & Lou, 1999). Recently, a statistical approach has been effectively used for prediction, process optimization, and process control in manufacturing areas (Montgomery, 1997). For example, Fuh and Wu (1995) and Chen and Lou (1999) proposed a statistical model for surface quality prediction in end milling operations.

In this research, a multiple linear regression (MLR)-based IPSRR system using a dynamometer was applied to predict surface roughness using cutting force, spindle speed, feed rate, and depth of cut as input parameters in end milling operations.

What We Did

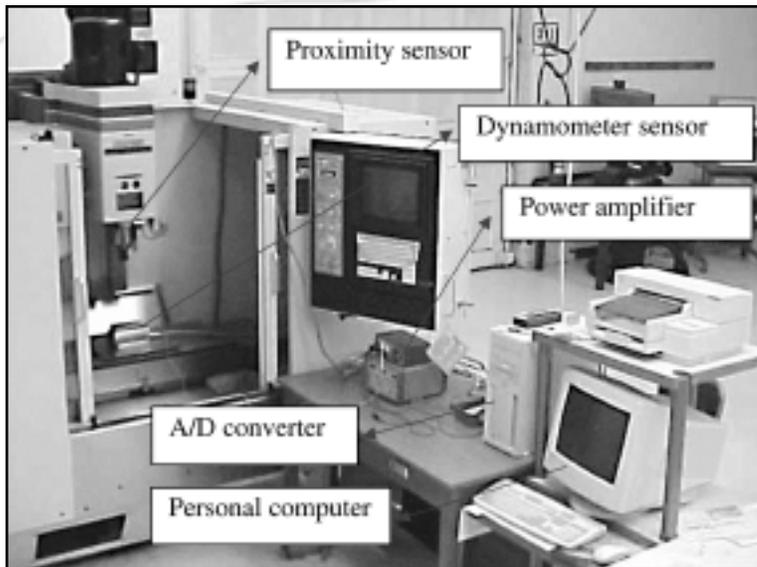
An MLR-IPSRR system was developed and implemented in two steps:

1. The magnitude of the cutting force in the end milling operation that had the highest correlation for predicting surface roughness of the finished parts was identified.
2. The MLR-IPSRR system, including the above-mentioned cutting force and cutting parameters, was developed and tested.

Procedure

Figure 1 illustrates the experimental setup consisting of the hardware and software used to accomplish the two steps.

Figure 1. Experimental setup for the proposed MLR-IPSRR system.



The hardware included:

- A Fadal vertical CNC milling machine with multiple tool changing and a 15 HP spindle.
 - A Kistler 9257B type dynamometer sensor, which provided dynamic measurement of the three orthogonal components of a force signal (F_x , F_y , and F_z).
 - A Micro Switch 922 series 3-wire DC proximity sensor, used to collect the signal for counting the rotations of the spindle as the tool was cutting.
 - A power supplier, used to amplify the signals from the proximity and the dynamometer sensors. This amplified signal was then sent to the A/D board.
 - An omega CIO-DAS-1602/12 A/D converter, used to convert both the dynamometer and proximity sensor data from analog to digital signals.
 - A P5 133 personal computer, which was connected to collect data from the A/D converter output via an I/O interface.
- A 6061 aluminum workpiece with dimensions of 1.00" x 1.00" x 1.00", which was cut in the end milling operations.

In order to control end milling operations and analyze the spindle revolution and cutting force signals, the following software was required: (a) Basic CNC codes, which were applied to conduct cutting operations, and (b) A/D converter software, which was used to convert data (proximity and cutting forces) from analog signals to digital values. Using the hardware and software setups, tests of cut were performed. Figure 2 shows the data obtained from this experimental run using spindle speed ($S = 2500$ rpm), feed rate ($F = 8$ ipm), and depth of cut ($D = 0.08$ in.).

The Cutting Forces Analysis

From Figure 2, the cutting force data were collected from the dynamometer sensor; these three forces (F_x , F_y , and F_z) cannot individually represent the actual force affecting surface rough-

Figure 2. Proximity and cutting force digital data using cutting condition $S = 2500$ rpm, $F = 8$ ipm, and $D = 0.08$ in.

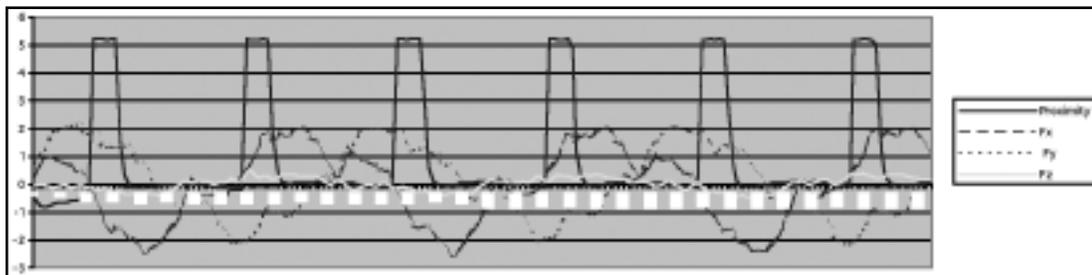
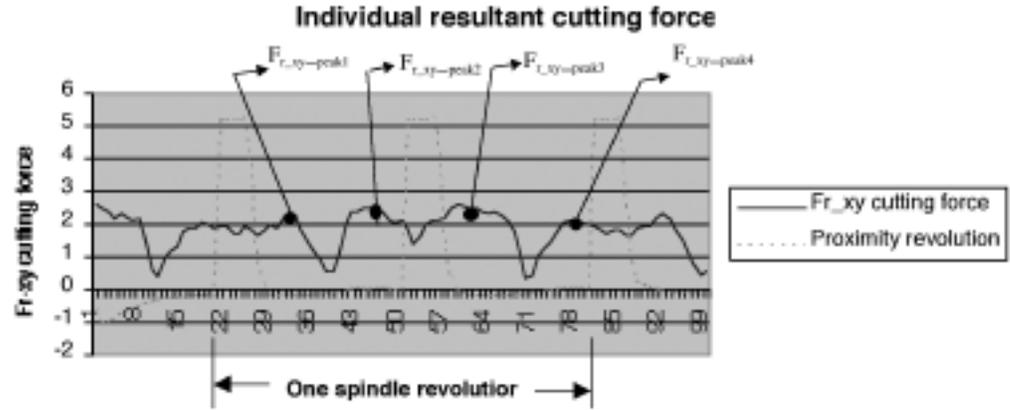


Figure 3. Individual resultant cutting force $F_{r,xy}$ and four peak forces in one revolution at cutting condition of $F = 20$ ipm, $S = 2000$ rpm, $D = 0.08$ in.



ness. Four cutting force magnitudes ($\overline{F}_{r,xy}$, $\overline{F}_{r,xy,peak}$, \overline{F}_z , and $\overline{F}_{r,xyz}$) were considered as possible candidates for an input factor for the MLR-IPSR system. They are defined as:

1. Average resultant force of the x and y directions per revolution ($\overline{F}_{r,xy}$).

By using the following equation, one could find the individual resultant force ($F_{r,xy}$) from the x and y directions as shown in Figure 3.

$$F_{r,xy,i} = \sqrt{F_{x,i}^2 + F_{y,i}^2}, \quad (1)$$

where i is the data point in one revolution.

Then, the average resultant force in one revolution ($\overline{F}_{r,xy}$) could be given as:

$$\overline{F}_{r,xy} = \frac{\sum_{i=1}^m F_{r,xy,i}}{m}, \quad (2)$$

where $i = 1, 2, \dots, m$ and m is the total data points in one revolution.

2. Average resultant peak force ($\overline{F}_{r,xy,peak}$).

By using the data shown in Figure 3, one could also identify the peak force ($F_{r,xy,peak}$) from the average resultant forces of the x and y directions ($\overline{F}_{r,xy}$) in the cut period of each tooth. Then, the average resultant peak force in each revolution ($\overline{F}_{r,xy,peak}$) could be given as:

$$\overline{F}_{r,xy,peak} = \frac{\sum_{i=1}^r F_{r,xy,peak,i}}{r}, \quad (3)$$

where $i = 1, 2, \dots, r$ and r is the number of cut-

ting tool teeth. In this study, $r = 4$.

3. Average z direction cutting force per revolution (\overline{F}_z).

The third type of force analyzed in this study was the average cutting force in the z direction per revolution (\overline{F}_z) and could be given as:

$$\overline{F}_z = \frac{\sum_{i=1}^m F_{z,i}}{m}, \quad (4)$$

where $i = 1, 2, \dots, m$ and m is the total data points in one revolution.

4. Average resultant force of x, y, and z directions per revolution ($\overline{F}_{r,xyz}$).

The researcher also wanted to analyze the average resultant force of the x, y, and z directions in one revolution ($\overline{F}_{r,xyz}$). The force is given as:

$$F_{r,xyz,i} = \sqrt{F_{x,i}^2 + F_{y,i}^2 + F_{z,i}^2}, \quad (5)$$

where i is the data point in one revolution.

Then, the average resultant force in one revolution ($\overline{F}_{r,xyz}$) could be given as:

$$\overline{F}_{r,xyz} = \frac{\sum_{i=1}^m F_{r,xyz,i}}{m}, \quad (6)$$

where $i = 1, 2, 3, \dots, m$ and m is the total data points in one revolution.

After the above-mentioned cutting forces were formed, we examined the correlation coefficient between these cutting forces and surface roughness. Equation 7 was used to compute the

correlation coefficient between surface roughness (Ra) and the average resultant force of the x and y directions ($\bar{F}_{r,xy}$).

$$\rho_{Ra-\bar{F}_{r,xy}} = \frac{\sum_{i=1}^n (Ra_i - \bar{Ra}) (\bar{F}_{r,xy,i} - \bar{\bar{F}}_{r,xy})}{\sqrt{\sum_{i=1}^n (Ra_i - \bar{Ra})^2 \sum_{i=1}^n (\bar{F}_{r,xy,i} - \bar{\bar{F}}_{r,xy})^2}} \quad (7)$$

where $\rho_{Ra-\bar{F}_{r,xy}}$ is the correlation coefficient between the average resultant cutting force ($\bar{F}_{r,xy}$) and surface roughness, Ra_i is the i th surface roughness, $i = 1, 2, \dots, n$ (n is total data sets; here $n = 384$), and $\bar{F}_{r,xy,i}$ is the i th average resultant cutting force of the x and y directions, $i = 1, 2, \dots, n$, (n is total data sets; here $n = 384$).

$$\bar{Ra} = \frac{\sum_{i=1}^n Ra_i}{n}, \quad \bar{\bar{F}}_{r,xy} = \frac{\sum_{i=1}^n \bar{F}_{r,xy,i}}{n}$$

Similarly, $\rho_{Ra-\bar{F}_z}$ and $\rho_{Ra-\bar{F}_{r,xyz}}$ were calculated. The largest value of correlation coefficients between the above-mentioned cutting forces and surface roughness represented the most significant cutting force, which was then used in the development of the MLR-IPSRR system.

Experimental Design

In order to identify the most significant cutting force for the MLR-IPSRR system, an experimental design matrix was used to run and collect the training data. The experimental design matrix, including eight levels of feed rate (6, 8, 10, 12, 14, 16, 18, and 20 ipm), four levels of spindle speed (1750, 2000, 2250, and 2500

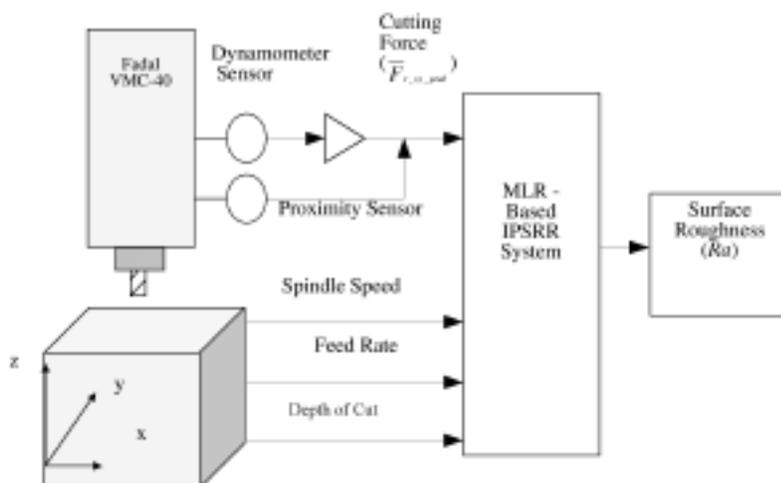
rpm), and three levels of depth of cut (0.04, 0.06, and 0.08 in.), was designed for the experiments with two replicates of each experiment. Two end milling tools (1/2 in. with four teeth) were used to cut the workpiece. Therefore, a total of $8 \times 4 \times 3 \times 2 \times 2 = 384$ sets of training data were collected. Cutting forces (F_x , F_y , and F_z) were collected using a dynamometer, as shown in Figure 1. The average resultant force of the x and y directions ($\bar{F}_{r,xy}$), average resultant peak force ($\bar{F}_{r,xy,peak}$), average cutting force of the z direction (\bar{F}_z), and average resultant force of the x , y , and z directions ($\bar{F}_{r,xyz}$) were calculated using Equations 2, 3, 4, and 5.

The 384 specimens were measured offline with a Pocket Surf stylus type profilometer (produced by Federal Products Co.) to obtain surface roughness (Ra) in this study. A JMP (a product of the SAS Institute) statistical software package was used to calculate the correlation coefficient between surface roughness and cutting forces. The results were $\rho_{Ra-\bar{F}_{r,xy}} = 0.49$, $\rho_{Ra-\bar{F}_{r,xy,peak}} = 0.53$, $\rho_{Ra-\bar{F}_z} = 0.46$, and $\rho_{Ra-\bar{F}_{r,xyz}} = 0.43$; therefore, the average resultant peak force of the x and y directions ($\bar{F}_{r,xy,peak}$) had the highest correlation coefficient with surface roughness and was selected as the input parameter for the MLR-IPSRR system.

The Proposed MLR-IPSRR System

After the most significant force was identified, the MLR-IPSRR system shown in Figure 4 was proposed. From Figure 4, one can see the

Figure 4. The structure of the proposed MRL-IPSRR system.



input parameters (average resultant peak force [$\bar{F}_{r_{xy_post}}$], spindle speed [S], feed rate [F], and depth of cut [D]) and the output parameter (surface roughness [Ra]) used to generate the MLR-IPSRR system. The proposed MLR-IPSRR system is given as:

$$\begin{aligned} Ra_i = & \beta_0 + \beta_1 F_i + \beta_2 S_i + \beta_3 D_i + \beta_4 \bar{F}_{r_{xy_post}} \\ & + \beta_{12} F_i * S_i + \beta_{13} F_i * D_i + \beta_{14} F_i * \bar{F}_{r_{xy_post}} \\ & + \beta_{23} S_i * D_i + \beta_{24} S_i * \bar{F}_{r_{xy_post}} \\ & + \beta_{34} D_i * \bar{F}_{r_{xy_post}} + \beta_{123} F_i * S_i * D_i \\ & + \beta_{124} F_i * S_i * \bar{F}_{r_{xy_post}} + \beta_{234} S_i * D_i * \bar{F}_{r_{xy_post}} \\ & + \beta_{1234} F_i * S_i * D_i * \bar{F}_{r_{xy_post}} + \epsilon_i \end{aligned}$$

where β are coefficients of the regression model, Ra_i is the surface roughness, F_i is the feed rate, S_i is the spindle speed, D_i is the depth of cut, $\bar{F}_{r_{xy_post}}$ is the average resultant peak force of the x and y directions, and $\epsilon_i \sim N(0, \sigma^2)$, where i is the number of data sets. To obtain data for the development of a multiple regression prediction model, a total of 384 experimental runs have taken place using the cutting combination indicated in the experimental design section. Therefore, in this study, $i = 1, 2, 3, \dots, 384$.

Analysis and Results of the System

After utilizing the JMP software package, the results of the surface roughness MLR model were generated as follows:

$$\begin{aligned} Ra_{(predicted)} = & 57.066 - 0.024 * S + 4.142 * F - \\ & 0.001 * (S - 2125) * (F - 13) + 491.056 * D + \\ & 0.630 * (S - 2125) * (D - 0.06) + 41.820 * (F - \\ & 13) * (D - 0.06) - 0.351 * \bar{F}_{r_{xy_post}} - 0.0007 * \\ & (S - 2125) * (\bar{F}_{r_{xy_post}} - 75.787) + 0.015 * \\ & (F - 13) * (\bar{F}_{r_{xy_post}} - 75.787) - 0.326 * \\ & (D - 0.06) * (\bar{F}_{r_{xy_post}} - 5.787) + 0.099 * \\ & (S - 2125) * (F - 13) * (D - 0.06) - 0.0001 * (S - \\ & 2125) * (F - 13) * (\bar{F}_{r_{xy_post}} - 75.787) + 0.01 * \\ & (S - 2125) * (D - 0.06) * (\bar{F}_{r_{xy_post}} - 5.787) + \\ & 0.722 * (F - 13) * (D - 0.06) * (\bar{F}_{r_{xy_post}} - 75.787) \\ & - 0.0016 * (S - 2125) * (F - 13) * (D - 0.06) * \\ & (-\bar{F}_{r_{xy_post}} - 75.787) \end{aligned}$$

The effect of tests showed that the feed rate, spindle speed, average resultant peak force, and depth of cut influenced the surface roughness significantly since the p values of each main effect (feed rate, spindle speed, average resultant peak force, and depth of cut) were less than a =

0.01 significant level). That is, the surface roughness was mainly determined by the feed rate, spindle speed, average resultant peak force, and depth of cut in end milling operations. The MLR model was also significant with the p value less than a = 0.01. Therefore, the MLR model can be effectively used in this research.

Once the MLR model had been established, the MLR recognition model was tested using 20 sets of cutting conditions that were different from the cutting conditions of experimental designs. The MLR-IPSRR model was implemented in the prediction of the surface roughness while the machining process was taking place. The results of the predicted surface roughness (Ra_i^{MLR}) were compared with the finished parts (Ra_{i-m}) that were measured by using a Pocket Surf portable surface roughness gauge. Then, the individual precision Φ_i^{MLR} of each experimental run (i) was evaluated based on the following equations.

$$\Phi_i^{MLR} = 1 - \frac{Ra_i^{MLR} - Ra_{i-m}}{Ra_i} \quad (8)$$

$$\bar{\Phi}^{MLR} = \frac{\sum_{i=1}^{20} \Phi_i^{MLR}}{20} \quad (9)$$

where Φ_i^{MLR} is the precision of i th testing run, and $\bar{\Phi}^{MLR}$ is the average precision of the 20 testing data, $i = 1 \dots 20$.

The results showed that the capability of the surface roughness prediction was about 86% for the testing experimental data in this study. Therefore, one can see that the surface roughness (Ra) can be predicted effectively by the above-mentioned MLR-IPSRR system.

What We Learned

The purpose of this study was to analyze cutting forces to find out the most significant cutting force magnitude that affected surface roughness and to evaluate whether a MLR approach for surface roughness recognition could be used for prediction in the IPSRR system. Our main conclusions are summarized as follows:

- The average resultant peak force ($\bar{F}_{r_{xy_post}}$) was identified to be the most significant force to affect surface roughness in this study.

- Spindle speed, feed rate, average peak cutting force, and depth of cut are significant in affecting surface roughness in end milling operations and the determination of the coefficient is R^2 of 0.62 in the MLR model.
- The MLR-IPSRR system is approximately 86% accurate in predicting surface roughness while the machining process is taking place.

This research assumed that the CNC milling machine was effective and stable to conduct all experiments under each cutting condition using an HSS end mill to cut 6061 aluminum material. We believe that the proposed IPSRR system could eventually be implemented in the new age of CNC machines. This would be more likely if additional research and testing could be done such as (a) including different

tool material, tool radius, workpiece material, and lubricants in the system and (b) using different methodologies, such as fuzzy logic, neural networks, and fuzzy nets, to provide the IPSRR system with a learning capability. With this capability, the system could be adopted to different machines produced from different CNC manufacturers.

Dr. Lieh-Dai (John) Yang is an associate professor in the Department of Industrial Management at Nan-Kai College, Nantou, Taiwan.

Dr. Joseph Chen is a professor in the Department of Industrial Education and Technology at Iowa State University. He is a member of Alpha Xi Chapter of Epsilon Pi Tau.

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Silicon Valley's Processing Needs Versus San Jose State University's Manufacturing Systems Processing Component: Implications for Industrial Technology

Samuel C. Obi

Background and Rationale

Manufacturing professionals within universities tend to view manufacturing systems from a global perspective. This perspective tends to assume that manufacturing processes are employed equally in every manufacturing enterprise, irrespective of the geography and the needs of the people in those diverse regions. But in reality local and societal needs influence the manufacturing processes employed by a region's manufacturers. To design better and more useful curricula that meet local needs, manufacturing systems professors and administrators need to understand the nature and magnitude of this issue.

Material processing is a major component of manufacturing systems (Seymour, 1995). All manufacturing programs emphasize material processing as a major component of their curricula. However, manufacturing processing needs in one geographical locality are often different from the needs in others. For example, while manufacturing companies in the mid-western and western United States may share commonalities in some processes, the differing needs of the two populations can result in companies of one locality emphasizing one or more processes more than the other, and vice versa. When such a situation exists, it is the responsibility of manufacturing educators and administrators to determine what changes are needed in their curricula to reflect local needs and what the local industry is doing. In other words, manufacturing processes employed by companies in a location are reflections of what manufacturing students in that location need to learn. This is important because most of their graduates get employed by companies located in that region. Addressing these regional differences in manufacturing process utilization constitutes the rationale for this study

To investigate how this applies to the manufacturing systems curriculum at San Jose State University (SJSU), a case study was undertaken in the spring of 2002. The results are contained

in this article, which examines the processing needs of manufacturers in the Silicon Valley of Northern California and compares the findings with the contents of SJSU's manufacturing systems program.

Procedure

This study was undertaken in two phases. The first phase determined which manufacturing processes generated more activities in the Silicon Valley of Northern California, as evidenced by the frequency of their use in the commercial advertising by the region's job shop manufacturers. An underlying assumption was that the frequency of use in a major advertising publication was an indication of the need and popularity of a process. To accomplish this, a special group of manufacturers was selected as the main population. This group included all the commercial and professional job shop manufacturers who participated in the 2001 and 2002 Job Shop Shows at the Santa Clara Convention Center. This annual, three-day business-oriented event is billed by its sponsors as the Southwest's largest contract manufacturing event ever. It attracts hundreds of manufacturing-related companies each year. These companies advertised numerous manufacturing processes as services that they provided, ranging from rubber forming to stamping and machining. The companies, together with their services, are published in the Job Shop Technology magazine, a quarterly publication serving manufacturers in the Silicon Valley (Short, 2001, 2002). These advertised processes were identified, sorted, and collated to determine their frequencies to help identify the advertised manufacturing processes that generated more or less activities among the job shops in the Silicon Valley region.

A total of 42 processes, together with their respective frequency scores for 2001 and 2002, were so identified. They included: brazing (4, 4); chemical etching (1, 3); coating (3, 4); deep drawing (3, 3); die casting (8, 9); die cutting (1, 4); EDM (7, 11); electroforming (2, 3); elec-

tron beam welding (1, 1); extrusion (12, 10); finishing (3, 8); grinding (3, 5); heat treating (2, 3); hydroforming (2, 1); injection molding (7, 13); investment casting (3, 1); laser cutting/drilling (5, 9); laser etching (2, 1); laser marking (4, 5); laser welding (2, 3); machining (42, 44); mold design (6, 1); molding (0, 2); perforating (1, 1); photochemical machining (3, 9); plating (4, 6); powder coating (2, 2); punching (1, 2); roll forming (0, 1); rubber molding (9, 8); sand casting (0, 1); sheet metal fabrication (6, 3); sheet metal forming (1, 5); springs (10, 11); stamping (18, 22); thermoforming (2, 2); thread rolling (0, 1); tooling design/fabrication (2, 5); tube bending (1, 1); water jet cutting (3, 3); welding (2, 9); and wire forming (9, 5). Processes that received a score of 5 or higher were given more attention in this study

The second phase of the study determined the degree to which SJSU's related manufacturing systems processing courses addressed these advertised processes. The premise here is that whatever is practiced by the manufacturing companies (which is an indication of what the society needs) is, to some degree, a reflection of what should be taught (Obi, 1991). To accomplish this, SJSU's manufacturing systems' key material processing courses were identified. They included: Tech 20 (Computer-Aided Design); Tech 046 (Introduction to Machining Processes); Tech 103 (Industrial Materials); Tech 104 (Manufacturing: Planning and Processes); Tech 142 (Product Prototyping and Manufacturing); Tech 143 (Polymers and Composites Fabrication Technology); and Tech 144 (Computer-Aided Manufacturing). The courses were then matched with their related processes according to their respective contents. This helps in visualizing processes that received coverage and those that did not, a picture that would help professors and administrators to make appropriate corrections if need be.

Findings and Discussions

The study revealed several observations:

- (a) one process received too much coverage,
- (b) some processes were covered adequately,
- (c) some processes received too little coverage,
- (d) some processes were not covered at all in the program, and
- (e) some processes were not

advertised but were taught in the program.

These processes and comments essentially constitute the findings from this study and are discussed in the following paragraphs.

It is encouraging to note that only one process (sand casting) appeared to be receiving too much coverage in the manufacturing systems concentration at SJSU. Perhaps this was because manufacturers now increasingly employ other casting processes. In fact, some casting processes such as die casting and shell mold casting have actually gained more popularity and use in recent years than other more traditional techniques such as sand casting. Fortunately, only one course (Tech 142) has a significant sand casting content. Perhaps, SJSU's manufacturing systems professors should switch to an alternative casting process to reflect current trends and help address this problem. If this happens to be the case, then consideration must be given to such factors as cost of die casting equipment, ease of maintenance, space availability, and so forth.

It was also encouraging that the study indicated adequate coverage of 25 (or about 60%) of the 42 processes advertised, including brazing, chemical etching, coating, deep drawing, die cutting, EDM, electron beam welding, finishing, grinding, heat treating, injection molding, investment casting, laser welding, machining, mold design, molding, perforating, punching, roll forming, sheet metal fabrication, sheet metal forming, thread rolling, tooling design/fabrication, water jet cutting, and welding. However, students received significant practical experience performing grinding, injection molding, machining, sheet metal fabrication, and tooling design/fabrication in courses containing those processes. But lectures, videos, and field trip activities alone provided enough learning experience for students in courses containing processes that received low advertising frequencies, since they are not considered to be high-demand processes.

On the other hand, the study indicated that eight processes received little coverage in SJSU's manufacturing systems program: die casting, extrusion, laser cutting/drilling, photochemical machining, plating, rubber molding,

stamping, and wire forming. Little coverage here means that these processes are covered only in classroom lectures, which does not match the high frequency scores received by the processes. Although the lectures often include videos and field trips, the actual performance of the process by students (a critical component of technology education) is missing. The absence of this applied component in a manufacturing systems program renders its graduates ill prepared to perform effectively when they enter the workforce. These graduates are expected to supervise working people and processes. A good familiarity with the processes that they will supervise will help equip them with the critical knowledge and skill needed in today's industrial environment.

Correcting this problem could require significant investment in equipment, space, and training, something SJSU's administrators are not willing to do because of their limited budget. But this is a problem that SJSU's manufacturing professors have to deal with in order to help meet those challenges and improve their manufacturing systems program. Therefore, some creative approach may have to be employed to address the problem. One possible idea is to help students complete their internships in companies where those processes are performed so they can learn those skills. Another idea may be to recommend that manufacturing systems students take courses containing those processes in a junior college and then transfer them to SJSU.

Of the eight processes that received no coverage at all in the program, namely, electroforming, hydroforming, perforating, plating, powder coating, spring forming, tube bending, and wire forming, only plating, spring forming, and wire forming are of major concern to the program because the rest did not receive as high scores as these three did. The processes that received lower scores can be included in lectures. But to implement plating, spring forming, and wire forming will again require significant investment in equipment, space, and training. Therefore, a possible solution here will be the industrial internship and junior college credit transfer ideas already discussed above.

The case of missing processes is the last observation to be mentioned here. These are processes that were not advertised by the participating companies but are taught in the program. Slush casting and open die forging, for example, were not advertised by the companies but are discussed in lectures at SJSU's manufacturing systems program. Such a situation may be due to a number of reasons, such as the case with a government contractor on specialized processes, a small business that cannot afford to participate in the show, a business whose process may not be needed locally, or simply a business that usually gets enough customers and does not care or want to participate in the job shop show. SJSU's professors and others in such a situation should use their judgment in configuring their curriculum to match companies' needs, especially if those same companies are also area employers.

It should also be mentioned that the view taken in this study represents only manufacturing-related entities that *actually* advertised their services in the job show. One should not interpret this group to represent all manufacturing companies in the Silicon Valley. Therefore, any major decisions made by SJSU's manufacturing systems professors and administrators from the results of this study should be made after other factors are considered. Such factors might include the robustness of the program, currency of the curriculum, enrollment trends in the program, and the general opinions about the program content as expressed by stakeholders such as students, parents, industry personnel, and other educators, especially community college instructors.

Implications for Manufacturing and Industrial Technology Programs

This case study was an attempt to determine the processing needs of Silicon Valley's manufacturers and compare them with the manufacturing systems processing component at SJSU. It also shows how the findings could be employed to reconfigure the curriculum to reflect local needs.

As has been demonstrated in the foregoing discussions, this kind of study helps educators and administrators to visualize the content mat-

ter of their programs more precisely and then determine whether they are meeting their intended goals and objectives. In other words, it acts as a tune-up whenever educators are in doubt about what they should be teaching. It also acts as a check and balance for a program. Since curriculum development is the core function of education, ensuring that essential and appropriate materials are covered in a program is critically important if manufacturing systems graduates are to be competently knowledgeable when they enter the workforce. This practice more directly affects the students and graduates of the region where the programs are located. Designing program content to reflect the industrial tasks of the area will certainly be a plus for the graduates and the manufacturing organizations that hire them when they graduate.

Also, this practice essentially makes the programs more functional in the communities that they serve. Students in such programs will more easily relate to the manufacturing jobs

advertised in their locality when they see one. And program educators and job providers will tend to be working together toward a common goal, since they can now see their commonality more easily. The result is that the manufacturing programs in the region will be more robust and the graduates more educated.

Finally, this study is recommended for all manufacturing programs, not only to help visualize how different localities and economies influence the manufacturing processes of their respective locations but also to ensure that the needs of students and employers in such regions are being met. It potentially can result in stronger manufacturing systems programs that will be in business for many years to come.

Dr. Sam C. Obi is an associate professor in the Department of Aviation and Technology at San Jose State University. He is a member of Rho Chapter of Epsilon Pi Tau.

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Creative and Collaborative Problem Solving in Technology Education: A Case Study in Primary School Teacher Education

Jari Lavonen, Ossi Autio, and Veijo Meisalo

Many public and private institutions believe that there is a growing need for employees who are able to think creatively and solve a wide range of problems (Grabinger, 1996). On the

other hand, several researchers have maintained that many of the skills and competencies needed in working life are seldom obtained at school (e.g., Resnick, 1986). Therefore, competency-

based or performance-based approaches to teacher education have been recommended in order to give students a broader perspective and to equip them to teach technology (Custer, 1994; Sinn, 1996; Whitty & Willmott, 1991). In particular, it has been argued that creative problem solving is an integral part of technology education, in contrast to an instruction-following method of technology education, reproducing artifacts, and teacher-dominated work (De Luca, 1993; Sellwood, 1991; Williams & Williams, 1997). Wu, Custer, and Dyrenfurth (1996) suggested even more forcefully that (creative) problem solving should be a core content area and method of teaching technology. These approaches particularly seem to fit technology-oriented modules in teacher education.

In this article, the Creative Technology Education Project (CTEP) is presented, and phases of problem-solving processes in which the participating primary school student teachers generate alternatives and evaluate ideas are analyzed. The aims of this project were to introduce technology education goals and contents to these students, as well as to offer tools for learning and teaching technology, and to facilitate personal growth. One purpose of the project was to encourage the students to become familiar with technology and problem-solving processes and to develop especially creative skills and abilities (e.g., ideation and the evaluation of ideas). For those purposes, a model was introduced, named the Overall Mapping of a Problem Situation (OMPS). This model helps students in ideation (the generation of alternative solutions) and evaluation of ideas when working on project teams. This model was practiced with concrete technology education projects. Thus, the project focus was on collaborative problem solving, with special emphasis on ideation and the positive evaluation of ideas.

Creative and Collaborative Problem Solving

Different ways to emphasize creative problem solving in small groups have been suggested (e.g., Dooley, 1997; Grabinger, 1996; Hill, 1999). A common feature of these approaches is to place students in the midst of a realistic, ill-defined, complex, and meaningful problem with no obvious or correct solution. Students work in

teams, collaborate, and act as professionals, confronting problems as they occur – with no absolute boundaries. Although they get insufficient information, the students must settle on the best possible solution by a given date. This type of multistaged process is characteristic of effective and creative problem solving. These stages may include (a) formulating the problem, (b) recognition of facts related to the problem, (c) goal setting, (d) ideation or generating alternatives, (e) the evaluation of ideas, (f) choosing the solution and, (g) testing and evaluating (De Luca, 1993; Fisher, 1990; Welch & Lim, 2000). The process is nonlinear and follows no particular rules because rational approaches miss the entire point of creative problem solving.

In accordance with Hennessy and Murphy (1999), the term collaboration is used in this article to describe social interaction within a group or a team, when students actively talk and share their cognitive resources, working together to produce a single outcome. They are also supposed to establish joint goals and referents, making joint decisions, solving emerging problems, constructing and modifying solutions, and evaluating the outcomes through dialogue and action. Collaboration requires students to actively communicate (e.g., negotiate or debate) and work together (e.g., set goals, plan, generate alternatives) with the aim of producing a single outcome (e.g., an object, a computer program, or a technological process/system). The students must then evaluate their outcome through dialogue and action (Hennessy & Murphy, 1999).

When problem solving is creative, the ideas or products produced during the problem-solving process are both original and appropriate (Fisher, 1990). For these purposes, various idea-generation techniques or ideation models are valuable (Smith, 1998). The number of alternative solutions is important because the best way to come up with good ideas is to have plenty of choice (Parker, 1991). Consequently, the outcome of creative problem-solving activities depends largely on the creative processes and ideation techniques that have been learned and applied. Furthermore, there are factors of attitude (interest, motivation, and confidence), cognitive ability (knowledge, memory, and thinking-skill), and experience (familiarity with con-

tent, context, and strategies) that influence problem-solving processes (Fisher, 1990). For example, nonjudgmental positive feedback and the acceptance of all ideas, even absurd or impractical ones, are important in all creative group processes for generating significant alternatives (Higgins, 1994). There should be room for free ideation sessions. Evaluative critiques should only take place afterwards.

Numerous models for curriculum changes in technology education, as well as for introducing creative problem-solving processes, are available nowadays in both technology education literature and school textbooks (Johnsey, 1995). Nevertheless, there still appears to be an overemphasis on passive learning and the old traditions of craft learning (Kimbell, 1997). Moreover, some renewed curriculum models lead easily to a situation in which the construction phase immediately follows the planning phase, without enough time for conceptualization, ideation, and the evaluation of ideas (Alamäki, 2000; Elmer & Davies, 2000). An especially important aspect of technology education and teacher education is providing the opportunity to get away from routine activities and low-level thinking so that students can find fresh new ideas and approaches, for example, by utilizing group dynamics or special creative methods (Smith, 1998).

There is an obvious need for young technology teachers to act as agents for change. Moreover, it is obvious as well that more research and development effort should be directed towards introducing creative problem-solving approaches in technology education (Gilbert & Boulter, 2000; Lee, 1996). Instruction and teaching models experienced during primary school teacher education often serve as learning models for students. The plan of the CTEP, described in more detail below, was based on the assumption that collaborative and creative problem solving would be valuable for developing a premium technology education study module for primary school teacher education. The purpose of the study presented in this article was to discover how students perceive the creative process and to what extent they learn creative skills, especially those that involve generating alternative ideas and the self-

evaluation of these alternatives.

The following questions guided this study:

1. What are the key factors in creative problem-solving processes from the point of view of primary school student teachers?
2. Have students learned creative skills during their enrollment in the CTEP?

The CTEP

The practical goal of the CTEP was to introduce student teachers to the OMPS method and to help them to become familiar with problem-solving processes, ideation techniques, and evaluation of ideas.

Of the 118 participating students, 80% were female and were on average 24 years old. According to the collected background information, 77% of the students had little or no previous knowledge or experience regarding the contents and methods of technology education. Less than 10% of them, however, disagreed with statements indicating high motivation and responsibility in their work, as well as success in planning and collaboration during the CTEP. Only about 15% of the participating students thought that the CTEP was of little significance to the primary school teaching profession or that the CTEP offers little that is applicable to their profession. It can be concluded, therefore, that the students' attitudes to the project were largely positive and that they agreed with the project goals.

At the beginning of the CTEP, the students attended four hours of lectures and demonstrations about creative problem solving. The sessions covered different idea generation techniques, such as brainstorming and analogous thinking. In addition, the students became familiar with the theme through WWW pages (Lavonen & Meisalo, 2001) that presented problem-solving models and a couple of idea-generating techniques, such as the OMPS (Sellwood, 1991). Different (e.g., creative, social, and personal) abilities and skills needed in creative problem solving, as well as ways to establish a creative and open atmosphere, were discussed. After the above-mentioned sessions, a four-hour workshop was organized in which the students worked in small groups. In these workshops,

Figure 1. An example of a planning process expressed by a map constructed during the creative phase. In this phase, the primary school student teachers utilized the OMPS-method.

The Problem: How to design a coaster for a coffee-pot in a creatively different way.			
Facts: - should insulate - be used on a table - 20 hrs to plan and make it - ...	Opinions: - beautiful coaster - always on display - wooden - not big - recycling materials	Goals: It should be - useful - easy to move - modern - ...	Visions: - Ideal for Y2K - Artistic
Approach A: interesting shape Idea A1: oval + traditional + easy to turn on the table + beautiful ? how to avoid familiarity ? how to inspire makers Idea A2: triangle + cups can be placed in the corners + innovative + interesting + easy to make from wood ? how to stick Idea A3: star... + ...	Approach B: coaster with layers Idea B1: two layers + kettle holder underneath + innovative + interesting ? how to prevent keeling over Idea B2: three feet and hooks for cups + innovative + interesting + can be moved with one hand ? how to prevent keeling over Idea B3: a candle can warm the coffee-pot from below + ...	Approach C: Integrated tray and coaster Idea C1: big wooden construction + practical as tableware + innovative + can be given as a present + embellishment for the table ? how to manage in time Idea C2: double heart + ... + ... + ... ? ... Idea C3: ... + ...	Approach D: box... Idea D1: tea bags in the coaster + easy to find + gift + innovative ? ... Idea D2: spice-rack integrated with the coaster + ideal for a party + easy to clean the table + ... ? how to manage in time Idea D3: ... + ...

students became familiar with the OMPS method by using it to plan a bridge or tower to be constructed out of newspapers.

During the planning phase of the project (four to eight hours), the groups of 3 to 4 students worked in 24 collaborative teams according to the basic principles of the OMPS method and generated a map of the creative process (see Figure 1). First, the students had to find, formulate, and specify the problem (*How could something be done differently?*) and recognize the facts (agreed by the team) and opinions related to the problem. Next, the teams set the problem or team assignments in a cogent phrase, such as: *How can an interesting electric toy be constructed differently? or How can a game be designed differently?* In addition, the students had to set the goals and visions (ideal performance). Then, the students had to create suitable approaches for solving the problem and to generate problem-solving alternatives. Every alternative idea was subsequently backed up by presenting at least three reasons for its adoption. Nonjudgmental positive feedback and the acceptance of all ideas, even absurd or impractical ones, were held as important rules during all

group processes that generated creative alternatives (Higgins, 1994). During the planning phase, the teams identified, on average, 3.8 (SD = 1.30) facts and expressed 2.1 (SD = 1.6) opinions related to the problem. The teams set, on average, 2.7 (SD = 1.0) goals and created 1.9 (SD = 1.2) visions. They generated, on average, 3.4 (SD = 0.59) problem-solving approaches and 7.3 (SD = 2.4) ideas as to how to solve the problem. In the subsequent maps, there were 13.6 (SD = 7.7) positive evaluations of the presented ideas and 3.9 (SD = 3.4) constructive “how” questions. Some teams presented their ideas in figures.

During the creative process, it was also possible to ask constructive questions about the idea or to combine, redefine, and piggyback ideas. After generating dozens of ideas, students chose the most appropriate solution by comparing the positive feedback and constructive questions that related to each idea. Typically, the final solution was a combination of several original ideas. During the ideation phase, the students were encouraged to follow the creative rules and to utilize idea generation techniques while working in collaborative groups. After

selecting the final ideas, students then planned out how they would construct the structure or perform the process.

After generating alternatives, evaluating them, and designing and planning the project, the students created something new in their design solution process utilizing paperboard, wood, metal, and/or plastic and the appropriate tools. The teams spent approximately 12 hours in the workshop and worked according to their previously agreed plans. It was intended that the students should be creative in their teams and that they would modify their preliminary plans during the practical work period. Finally, each team presented their innovations to the other groups and evaluated both the innovations and the entire process, first by themselves and then with the others. The construction and evaluating phases are not included in this article.

Implementation of the Study

This research can be described, in accordance with Stenhouse (1985), as exploratory evaluation research, in which data were gathered to evaluate the CTEP described above. It is a typical case study in which different approaches to data gathering is used, including gathering data in numerical form. Moreover, the study also has features of developmental research, which Richey and Nelson (1996) defined as a systematic study of designing, developing, and evaluating instructional programs, processes, and products that must meet the criteria of internal consistency and effectiveness.

For evaluating the creative problem-solving processes, a questionnaire consisting of 23 items was utilized, thereby yielding self-evaluative data concerning the students' success as regards the conceptualization and evaluation of ideas, as well as on their success with creative problem solving. The items were formulated on the basis of theoretical ideas about features of creative problem-solving processes presented in the theoretical framework of this article. For each Likert-type item, there were five alternatives, varying from *strongly disagree* (1) to *strongly agree* (5). The questionnaire included some items about the students' background as well as items about their motivation and general success during the teaching experiment.

The items were located randomly in the questionnaire, which was accessible over the Internet, and the students were asked to fill in the forms after the last meeting. Eighty-five students out of the 118 students who participated in the project answered the questionnaire. A preliminary item analysis based on item-to-item correlations and item-to-total score correlations led to the elimination of four of the questionnaire items. For example, the item *I learned to support the self-respect of other students* only had a 0.15 correlation to the total score and was, therefore, rejected from the final analysis. It is obvious that the students must have misunderstood the rejected items or that the items were ambiguous. On the other hand, it is also possible that the students did not agree with the rejected items. The internal reliability of the remaining 19 items was high (Cronbach alpha = .89).

An exploratory factor analysis was used to reduce the large number of original variables to a smaller number of factors and to examine how the problem-solving process was experienced by the students. The Kaiser-Meyer-Olkin measure was within a very reasonable range; KMO = .80 (Norusis, 1988). Bartlett's test of sphericity also supported the use of a factor analytic approach (Bartlett's test = 845.9, $p < .00001$).

Results

The questionnaire data were analyzed with the SPSS program, utilizing principal axis factoring as the extraction method and varimax with Kaiser normalization as the rotation method. This method was used to determine how students experienced the key factors in their creative problem-solving processes. The exact number of factors was determined by means of Cattell's scree-test. The comprehensibility criteria were also used, and the number of factors was limited to four, since the meaning of the factors was then readily comprehensible (Dunteman, 1989). To determine the internal consistency of each factor, a Cronbach alpha coefficient, based on the average interitem correlation, was determined for each factor. The Cronbach alpha coefficients of the factors varied between 0.83 and 0.88. Each factor, therefore, measured one quality and, thus, a meaningful interpretation of the factors was possible. On the other hand, no far-reach-

ing generalizations were allowed regarding the structure or properties of the problem-solving processes. The factor analysis simply made it easier for us to describe how these 85 students experienced creative problem-solving processes during the CTEP.

On an aggregate level, these four factors explained 57.2% of the common variance, with eigenvalues of 6.19, 2.14, 1.42, and 1.13, and percentages of total variance of 32.57%, 11.26%, 7.46%, and 5.96%, respectively. The communality, 57.2%, indicated that four factors could be used satisfactorily as predictors for all 19 variables. Moreover, the extent to which each item played a role in the interpretation of the factors was high. The eigenvalues indicated that Factor 1 covered most of the variance, and the other factors each contributed about the same amount to the explanation of the variances.

Each of the four factors indicating the students' perspectives regarding problem-solving processes and variables (items) that described the highest loading on each factor are presented in Table 1. Three items also had loadings over 0.30 on other than their main factors, and these are commented upon below. The factors were labeled on the basis of researcher discussion on variables (items) loading on a factor. The means and standard deviations of each item are also presented in Table 1.

Factor 1, *success in problem-solving processes*, explained 32.5% of the total variance and included seven items. The first two items (F1-I1 and F1-I2) loading on this factor are connected to the problem-solving processes. Recognizing problems in one's surroundings (F1-I6) and restricting a problem (F1-I7) belong to the first phase of the process and are, therefore, a natural starting point for the problem-solving process. The creative atmosphere that is indicated in items F1-I5 and F1-I3 is necessary to establish a creative problem-solving process, but it is not sufficient to ensure that one can be launched. Another prerequisite for success would be knowledge about ideation techniques and ideation skills. These perspectives to problem-solving processes are indicated in items F1-I3 and F1-I4, which describe perspectives for ideation, but they do not tell how students suc-

ceeded in generating alternatives or about the quality of their ideation. On the other hand, these items also had high loadings (0.47 and 0.43) to the second factor dealing with the students' success in ideation.

Factor 2, *productive ideation*, consisting of six items, explained 11.3% of the variance indicating students' opinion about their ideation skills. Two items (F2-I1 and F2-I4) indicate the quality of the ideas. It is important that ideas generated during a creative process are original—otherwise one should label the process as routine. It is also important that the students learn to combine and develop others' ideas further. The key issue for success in creative processes is how the creative power of the group can be utilized in finding fresh ideas. The number of ideas (F2-I2, F2-I5) is also connected to their quality. It is known that in the beginning of an ideation session common, familiar ideas typically come to mind. Therefore, if there are many ideas in the group, at least some of them will be of high quality. It is important to use creativity (F2-I6) and to be both intuitive and systematic in turn (F2-I3) during the process of ideation. Item F2-I6 also had a high loading (0.40) on the fourth factor, which in this case dealt with positive attitude.

Factor 3, *collaborative support and evaluation*, consisting of four items, explained 7.5% of the variance. Items F3-I1 and F3-I4 indicate that students learned to express their feedback positively and constructively. The two remaining items (F3-I2, F3-I3) deal with positive attitudes when evaluating ideas.

The remaining two statements loaded on Factor 4, *positive attitude*, explained 6.0% of the variance. Item F4-I1 indicates that students behaved positively, and the other item (F4-I2) deals with a positive attitude as regards the creative process.

Means of the first two items loading on Factor F1 were 3.6 and 3.7. Thus, most students thought that they had learned about the nature of creative processes and how to work according to the principles of creative processes as well. This is what was expected, since these topics were emphasized during both the lecture and the

Table 1. Means and Standard Deviations and Varimax, with Kaiser Normalization Rotated Factor Loadings for Principal Axis Factoring, Calculated for the Items Measuring Primary School Student Teachers' Opinions About the Creative Process in the Project

	Mean	SD	Factor Loading
F1: Success in problem-solving processes			
Cronbach's alpha for the factor = 0.84			
F1-1: I learned to generate original ideas	3.37	84	.507
F1-2: I learned about the initial and final creative processes	3.32	92	.851
F1-3: The level of the solution "is it possible to generate new alternatives?"	3.55	90	.595
F1-4: I learned to generate ideas	3.07	90	.570
F1-5: I learned to generate a creative atmosphere	3.11	92	.567
F1-6: I learned to recognize problems around me	3.20	90	.160
F1-7: I learned to identify real and realistic problem	3.65	78	.115
F2: Productive ideation			
Cronbach's alpha for the factor = 0.84			
F2-1: I learned to generate original ideas	3.38	88	.769
F2-2: I learned to generate more alternatives	3.20	85	.767
F2-3: I learned to evaluate the ideas of other students	3.37	93	.695
F2-4: I learned to evaluate further ideas presented by other students	3.22	90	.578
F2-5: I learned to trust the group to have many ideas, at least some of them will be high quality ideas	3.51	85	.558
F2-6: I used my creativity	3.48	94	.187
F3: Collaborative support and evaluation			
Cronbach's alpha for the factor = 0.87			
F3-1: I learned to give positive feedback to other students' ideas	4.02	77	.882
F3-2: I learned to appreciate others' ideas	4.19	76	.845
F3-3: I learned to bring advantages of the ideas of others	4.14	84	.877
F3-4: I learned to give constructive feedback to the views of other students' ideas	3.91	78	.646
F4: Positive attitude			
Cronbach's alpha for the factor = 0.85			
F4-1: I am positive in creative processes	3.50	82	.530
F4-2: I took up positive attitude to creative processes	3.63	91	.726

workshops. Much time was also spent on understanding the meanings of ideation and the evaluation of ideas. Means of the items loading on the second factor indicate that, according to the self-evaluative data, the students had learned (at least reasonably well) to generate alternatives. Means of all items loading on the third factor indicate that the students had, in their own opinion, learned how to give positive and constructive feedback regarding other students' ideas. One may also note that much was discussed as regards how to give constructive feedback, which was also practiced during the project. Even the meaning and the value of such behavior during creative processes were discussed. The students were familiar, for example, with how positive feedback defines what is valuable in an idea presented by another student. Positive feedback also indicates where or from which direction possible solutions can be found. Moreover, positive peer feedback is important for the self-respect and confidence of other students.

Discussion

Based on the identified factors, the means and standard deviations of the self-evaluative

data on creative process skills, and the primary school student teachers' maps, it could be effectively argued that the OMPS method helps students understand the nature of creative processes and, particularly, that there are different phases involved in each of these processes. The mean (3.7) of item F1-17 indicates that the students believed that they had learned to identify and restrict a problem. This is one of the most important phases in problem solving (Sapp, 1997). Factors 2 and 3 indicate that the students believed that they had succeeded in generating alternatives and, in particular, to evaluate and appreciate others' ideas. This means that the students felt that they had learned to give positive feedback regarding other students' ideas, to recognize the advantages of those ideas, and even to develop them further. It is obvious that a formal method in which each idea has to be backed up by the presentation of at least three reasons for its adoption is necessary for success. Such evaluation creates a nonjudgmental positive atmosphere for creativity, and it helps to behave positively as indicated in Factor 4.

On the other hand, the number of approaches ($M = 3.4$) and ideas ($M = 3.3$) generated during

the ideation phase was comparatively low. This was reflected by the students' opinion on the item I learned to generate original and new ideas. The mean of this item (3.4) was one of the lowest. Furthermore, the students felt that they did not learn enough about the generation of many original and new alternatives. Those skills are important when extremely new alternatives are wanted (Amabile, 1996). From the point of view of similar projects, it is important to observe that more efficient guidance in generating alternatives is needed. Students should be carefully introduced to techniques that can be used for generating numerous alternatives because the best way to get good ideas is to have plenty to choose from. It can be concluded that the outcomes of creative problem-solving activities depend on the creative processes as well as ideation techniques learned and applied (Smith, 1998).

The items measuring the students' success in the ideation and evaluation of ideas loaded on different factors. This result means that the students succeeded in separating those aspects when evaluating their problem solving. Both abilities (ideation and the evaluation of ideas) are essential for creative problem solving as well as the ability to segregate them. The ways in which the human mind works when creating new ideas can be argued. As de Bono (1970) emphasized, critical thinking is needed when

one is evaluating ideas and in the open creative thinking that is required to generate alternatives.

In summary, this case study indicates that creative problem-solving approaches may be efficiently used to improve teacher education. On the other hand, students must be encouraged to create many possible solutions to problems and then to select the best ones. Furthermore, students should receive a thorough introduction to creative problem solving in general (Williams & Williams, 1997). Such training could be beneficial because many students in our study became anxious when no formula existed or no direct guidance was given to their work. In addition, the recognition of facts connected to the background of the problem proved to be important in this study. Thus, it is essential for the creative process that students have relevant information available.

Dr. Jari Lavonen is a senior lecturer and docent in science and technology education at the University of Helsinki and the president of the Finnish Mathematics and Science Education Research Association.

Dr. Ossi Autio is a professor in Skill and Arts Education at the University of Helsinki.

Dr. Veijo Meisalo is a professor of pedagogy of mathematical sciences and the head of the Department of Teacher Education at the University of Helsinki.

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The Effect of Problem-Solving Instruction on Children's Creativity and Self-efficacy in the Teaching of the Practical Arts Subject

Namyong Chung and Gyoung-sug Ro

Theoretical Framework

Practical arts is a subject that not only promotes learners' better understanding of work in their daily lives, but also enables them to find ways to solve work-related problems by fostering basic skills and attitudes necessary for performing the work (Ministry of Education, 1993). That is why the Ministry of Education in Korea (1993) identified the practical arts subject as a "practical living" subject, a "creative problem-solving subject," and an "integrated knowledge subject." Moreover, practical arts education in the aspect of its educational goal helps develop students' problem-solving and creative-thinking skills. In the methodological aspect, it also develops students' self-efficacy by helping them acquire daily living skills as well as the joy of work experience and a sense of accomplishment through experiential learning based on the work experience (Ministry of Education, 1993). That's why the Ministry of Education made the practical arts subject a required course for the elementary education system in Korea.

The teaching of practical arts as a subject should be focused on developing creativity and self-efficacy by the active employment of scientific thinking through the activity-centered decision-making process. Plus, the teaching of the practical arts subject must be conducted accord-

ing to the problem-solving model (Kwak, 1988; Seoul-Inchon Area Research Association of the Practical Arts Education, 1995; Research Association of the Practical Arts Education for All Korea National Universities of Education, 1997). However, most elementary school teachers in Korea have used the typical instruction method (lecture) to teach students the practical arts subject.

Choi (1997) suggested that practical arts education should be performed based on work experience activities by using problem-solving methods since the assumption of a model for the problem-solving method lies in the reflective thinking process; learners by themselves try to study creatively or reach conclusions comprehensively. And Kwak (1988) emphasized that the topics of practical arts education need to be taught by the problem-solving method while considering the necessity of problem-solving ability and creative thinking.

Na (1997) insisted that practical arts instruction should signify learner-centered instruction (i.e., learning by doing, using the various methods such as investigation, discussion, experiment, and work experience). While considering what students learned in previous instruction, then practical arts teachers could

Table 1. The Sexual Distribution of Subjects in the Study

Type	Male	Female	Total
Experimental	17	16	33
Control	16	17	33
Total	33	33	66

R ₁ (Problem-Solving Instruction Group)	O ₁	X ₁	O ₂
R ₂ (Problem-Solving Instruction Group)	O ₃	X ₂	O ₄

R1 : experimental group	X ₁ : problem-solving instruction	O ₁ , O ₃ : pre-test
R2 : comparative group	X ₂ : typical instruction	O ₂ , O ₄ : post-test

Figure 1. Quasi-experiment design.

Table 2. Creativity Measurement Factors and the Test Content

Factors	Time	Test Content
Fluency	3 min	As many imaginary words as possible to a given word should be written down within the time limit.
Flexibility	3 min	Many things which can be expressed in number in everyday life should be written down in number within the time limit.
Originality	4 min	By using the given vertical line, a student is required to draw a certain shape, and put down its name below it. The score is given only when the shape is unique. The drawing is graded according to the content of the shape.

Table 3. Comparison Between Problem-Solving Instruction and Typical Instruction

Problem-Solving Instruction		Typical Instruction	
Step1	Motivation	Introduction	Recalling the previous learning
Step2	Group objectives		
Step3	Confirmation of problems to solve	Development	Teacher-centered development of the current lesson
Step4	Problem-solving		
Step5	Test of solutions through application	Consolidation	Consolidating the current lesson
Step6	Evaluation of the solutions		

apply the content of the subject in the real situation by giving a sense of accomplishment as well as self-efficacy. Na added that in particular there should be priority in the student-centered problem-solving instruction so that creativity and self-efficacy could be developed.

But there exists a remarkable difference between the reality in educational fields and the researchers' insistence based on the result of the studies on problem-solving ability, creative thinking, and self-efficacy as shown in the above studies. In other words, creativity education as specified in the characteristics and goals of practical arts education has not been conducted properly, not to mention the lack of the establishment of a theoretical foundation for creativity education in the practical arts. However, Chung (1997) provided the theoretical foundation of creativity education in practical arts by analyzing the factors of creativity and their relation to the content of the practical arts subject and presenting the factors of the representative learning content for practical arts in each grade.

Hence, this study has two significant points: one is the examination of the effects on children's creativity and self-efficacy by apply-

ing problem-solving instruction in practical arts education, and the other is the implementation of the first study in Korea on problem-solving, creativity, and self-efficacy with the potential for further research.

The purpose of this study was to examine the effects on children's creativity and self-efficacy by applying problem-solving instruction in practical arts education and to show how this is reflected in the literature of problem-solving learning. The following delineations are the specific objectives used to achieve this purpose:

1. Identify the effects of problem-solving instruction on the development of children's creativity.
2. Identify the effects of problem-solving instruction on the children's self-efficacy.

Subjects for Study

For the subjects of this study, two out of seventh grade classes at H Elementary School in the city of Pohang, Kyungsanpook-do, Korea, studying practical arts as required in all Korean elementary schools were chosen as the experimental and comparative classes. The experimental group received problem-solving instruction for two hours a week, and the con-

Table 4. A Form for Problem-Solving Instruction

I. Unit and Theme
II. Analysis of the Actual State
III. Instructional Objectives
IV. Procedure of Teaching
1. Motivation
2. Expected Objectives of the Student Group
3. Expected Problems
4. Plan for Solving Each Problem
Problem 1: " method ≠ data Æ summary
Problem 2, 3, 4, ... problem N
V. Application of Learning
VI. Reference and Teaching Aids
VII. Procedure of Assessment

Table 5. The Results of the Creativity Pre-Tests

Subarea	Class	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Frequency	Control	33	5.15	2.15	64	1.18
	Experimental	33	5.97	3.37		
Flexibility	Control	33	3.64	3.51	64	- 0.18
	Experimental	33	3.52	2.24		
Originality	Control	33	10.36	5.28	64	0.88
	Experimental	33	11.70	6.94		
Total (Creativity)	Control	33	19.75	8.03	64	0.92
	Experimental	33	21.18	9.38		

control group received typical instruction without emphasis on problem solving with all other factors being constant. The duration of the study was five weeks from May to June of 1999. The demographic information on the participating students is presented in Table 1.

Research Design

This study shows the progress of creativity and self-efficacy in the experimental and control groups after the experimental group received problem-solving instruction and the control group received typical instruction (i.e., without the problem-solving emphasis). Thus, the independent variables in this study were, as instructional methods, problem-solving instruction (for the experimental class) and typical instruction with no problem-solving component (for the control class). The dependent variables were the post-test scores of the creativity and self-efficacy tests. Figure 1, a diagram of the experimental design, examines the assumptions of the study.

Instrumentation

The existing creativity test instruments were not fit for the subjects and purpose of this study

since the instrument was made primarily for the target of upper grade students. Recently, for the third grade students, the Korea Creativity Research Institute (1998) developed the Creativity and Thinking Test with subareas for fluency, flexibility, and originality. The reliability of the creativity test was 0.93. The measurement factors and the test content are shown in Table 2.

The Self-Efficacy Test instrument was employed to measure the general level of self-efficacy on learning. In this study, the revised self-efficacy test from Sherer and Adams' (1983) questionnaire and Chung's (1987) questionnaire were employed (Cronbach alpha = 0.824).

Procedure

Homogeneity Test

In order to show the homogeneity between the experimental class and the control class, a pre-test was given to 246 students from seven third grade classes on Monday, April 26, 1999 (i.e., two weeks before the experiment). After the pre-test, two classes were chosen that showed little difference in the test, meaning

Table 6. The Results of the Self-Efficacy Pre-Tests

Type	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Control Experimental	33	80.52	17.61	64	1.27
	33	85.52	14.13		

Table 7. Comparison of the Pre-Test and Post-Test Results in the Creativity of the Control Class

Subarea	Test	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Frequency	Pre-test	33	5.15	2.15	32	6.84**
	Post-test	33	8.76	3.36		
Flexibility	Pre-test	33	3.64	3.51	32	2.49*
	Post-test	33	4.85	2.17		
Originality	Pre-test	33	10.36	5.28	32	-
	Post-test	33	10.36	5.28		
Total (Creativity)	Pre-test	33	19.75	8.03	32	6.94**
	Post-test	33	23.97	6.69		

* $p < .05$. ** $p < .01$.

Table 8. Comparison of the Pre-Test and Post-Test Results for Self-Efficacy in the Control Class

Type	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Pre-test	33	85.52	14.13	32	- 2.44*
Post-test	33	80.52	11.92		

* $p < .05$.

those two classes were not different in the aspect of students' creativity and self-efficacy. For the necessary time of the test, 30 minutes was allotted to the pre-test in considering the degree of students' attention and the range of the questionnaire. The post-test was administered in three weeks on July 5, 1999, after the experimental treatment (five weeks in total from May 10 to June 12, 1999). The test methodology and the time allotted for the post-test was equal to those of the pre-test.

Experiment Treatment

For the experimental treatment, the practical arts subject teaching plans with the problem-solving instruction component and the typical instruction method without such a component were approved by a preliminary examination of leading educators and elementary school teachers with expertise in the area. These two types of teaching plans are presented in Table 3.

Procedure of the Experiment

The teacher of the control class, who had almost equal educational experience in comparison with the teacher of the experimental class (researcher), clearly perceived the difference between problem-solving instruction and typical

instruction. The control class teacher was asked to conduct the instruction to the complete fulfillment of the constituent principle of each aspect of instruction.

The following control conditions were enforced to ensure the effects of this experiment:

1. Qualitative control: the instruction of the experimental class was implemented by the researcher
2. Quantitative control: two classes were equally conditioned in the progression of the instructional period and learning
3. Methodological control: the problem-solving instruction was implemented in the experimental class while the typical instruction was implemented in the control class
4. Content control: although the instructional style for the class was different, the content-instruction was equal.

Analysis of Data

This study aimed to investigate whether or not there was a meaningful difference in the degree of students' creativity and self-efficacy between an experimental group with problem-solving instruction and a comparative group

Table 9. Comparison of the Pre-Test and Post-Test Results in Creativity of the Experimental Class

Subarea	Test	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Frequency	Pre-test	33	5.97	2.15	32	6.08**
	Post-test	33	9.21	3.36		
Flexibility	Pre-test	33	3.64	3.52	32	5.03*
	Post-test	33	4.85	5.70		
Originality	Pre-test	33	10.36	11.70	32	7.84**
	Post-test	33	10.36	21.76		
Total (Creativity)	Pre-test	33	19.75	21.18	32	9.778**
	Post-test	33	23.97	36.67		

* $p < .05$. ** $p < .01$.

Table 10. Comparison of the Pre-Test and Post-Test Results in the Self-Efficacy of the Experimental Class

Type	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Pre-test	33	80.52	17.61	32	1.67
Post-test	33	83.79	17.25		

with traditional instruction. The collected data were analyzed by SPSS WIN, 7.5 version. Frequency, percentage, average, and standard deviation were employed, and the *t* test was also used to make a comparative analysis between the results from the experimental class and the control class.

Results

Homogeneity Between the Experimental Class and the Control Class

With the purpose of estimating the homogeneity between the experimental class and the control class, pre-tests of creativity and self-efficacy were conducted. The results of the pre-test presented in Table 5 showed no meaningful statistical difference between the two classes, and likewise in creativity subareas including fluency, flexibility, and originality. So, in the aspect of creativity, the experimental class and the control class should be regarded as identical.

The pre-test results for students' self-efficacy in the experimental and the control class indicated, as in Table 6, no meaningful difference. Thus, the two classes were equal in the aspect of self-efficacy.

Comparison of the Pre-Test and the Post-Test of the Control Group

The pre-test and post-test comparison results of students' creativity in the control class are shown in Table 7. There was a significant

difference between the pre-test result and the post-test result in creativity, and likewise in the tests of creativity subareas including fluency and flexibility. However, the pre-test and the post-test in originality as a subarea of creativity showed no significant statistical difference.

The pre-test and post-test for self-efficacy in the control group showed a statistically significant difference as shown in Table 8, but the score for the control class was found to be lower than before the experiment.

Comparison of the Pre-Test and Post-Test in the Experimental Group

The pre-test and post-test results in students' creativity indicated that there was a statistically significant difference between the pre-test and the post-test results since the creativity test score was increased in accordance with the experimental treatment with problem-solving instruction as indicated in Table 9. Moreover, there were significant differences in the creativity subareas, which included fluency, flexibility, and originality. This confirmed that the problem-solving instruction could enhance the subareas of creativity.

The pre-test and post-test results for self-efficacy showed no statistically significant difference as shown in Table 10, but there was a minor increase in the average of the test scores.

Table 11. Comparison of the Post-Test Results in Creativity in the Control Class and the Experimental Class

Subarea	Test	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Frequency	Pre-test	33	8.76	3.36	64	0.46
	Post-test	33	9.21	4.62		
Flexibility	Pre-test	33	4.85	2.17	64	1.27
	Post-test	33	5.70	3.18		
Originality	Pre-test	33	10.36	5.28	64	6.31**
	Post-test	33	21.76	8.92		
Total (Creativity)	Pre-test	33	23.97	6.69	64	5.04**
	Post-test	33	36.67	12.83		

** $p < .01$.

Table 12. Comparison of the Post-Test Results for Students' Self-Efficacy in the Control Class and the Experimental Class

Type	<i>n</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i> value
Pre-test	33	80.06	11.92	64	1.02
Post-test	33	83.79	17.25		

Comparison Between the Post-Test Results in the Control Class and the Experimental Class

The result of the post-test for students' creativity showed that there was a statistically significant difference between the control class and the experimental class as indicated in Table 11. In the creativity subareas, the aspects of fluency and flexibility showed no statistical significant difference between the two classes, but in the aspect of originality, a significant difference between the two groups was demonstrated. For this reason, the problem-solving instruction could be said to have more impact on the advancement of creativity than in the case of traditional instruction.

Although the post-tests for self-efficacy in the control group and the experimental group showed no statistically significant difference as shown in Table 12, the comparison of average scores on the post-tests for students' self-efficacy indicated higher scores in the experimental class than in the control class.

Conclusions and Discussion

The findings reflect several significant differences between the typical instruction group and the group with the problem-solving component. From the findings, the following conclusions can be drawn:

1. The problem-solving instruction showed a marked effect on originality, whereas the

other creativity subareas, including fluency and flexibility, showed just a slightly higher average not large enough to be statistically significant. The reason for not showing a statistically significant difference in fluency and flexibility might be the short period of the experiment's duration. Therefore, using problem-solving instruction in the long term can also have an effect on other subareas of creativity.

2. The problem-solving instruction within the context of practical arts class showed no statistically significant difference in students' self-efficacy, but the experimental class got a higher average score on the post-test. This might also be caused by the short period of the experiment's duration.
3. In the traditional instruction without the problem-solving component, students' self-efficacy was significantly lowered after the instruction period. This result could have been caused by (a) the short-term experiment or (b) the control group teacher who used a bad teaching skill. However, this result still indicates that typical instruction can be an obstacle in the development of children's self-efficacy.

All the details above indicate that the problem-solving instruction for elementary school children is related to the teaching-learning process in promoting children's creativity.

However, previous research on the effect of problem-solving instruction has suggested that it is difficult to draw a general conclusion that one process of instruction is always more effective than others. This is why one kind of teaching-learning process does not necessarily or consistently work better than others. Moreover, change in self-efficacy during the short term is hard to assess. Thus, only after the steady use of problem-solving instruction can a positive change in children's self-efficacy likely be noted.

Recommendations

The following recommendations are based on the findings and conclusions of this study:

1. Research on various methods to develop creativity and the development of an instructional model and learning materials are needed.
2. The positive effect of problem-solving instruction can be expected in subjects other than practical arts if problem-solving instruction is employed. Therefore, the experimental study of problem-solving instruction compared with traditional non-problem-solving instruction is suggested.
3. Long-term study of the promotion of creativity and development of curricula connecting elementary and secondary education is recommended.
4. This study has significance in the point that there was an attempt to promote creativity by using problem-solving instruction in the teaching of practical arts and that this study can be utilized in other subjects as well.

The theories and research with positive results for children are not supposed to be directly used without any pre-examination or regard of the students (subjects). Instead, there should be an understanding of children's abilities and verification of the effects of theories and methods suitable for children by carefully examining them prior to implementation.

Dr. Namyong Chung is an assistant professor in the Department of Practical Arts Education at the Daegu National University of Education, South Korea. He is member-at-large of Epsilon Pi Tau.

Gyoung-sug Ro is a teacher at Pohang Honghae Elementary School, South Korea.

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Energy Technology: A Cross-Curricular Approach in Japan

Sadato Yamazaki, Cyril King, Mika Shinde, Osamu Ohiwa, and Sohichiro Hirai

This article briefly describes a curriculum study that had two main purposes. The first purpose was to develop and reflect upon a new energy technology curriculum at the lower secondary school level using an action research method. The second purpose was to determine the effect of collaborative activities, with the families of the pupils enrolled in the curriculum, as a means to help develop pupils' cross-curricular competence.

Yamazaki (1999a, 1999b), Yamazaki and King (1998), and Yamazaki, King, and Preitz (2000) proposed conceptual frameworks for curricular themes and activities for technology education based on a whole curriculum concept. The authors gave serious consideration to both accountability and collaboration between the school, family, and community. In order to emphasize the interdisciplinary relationship between each technological activity and other subject areas, the authors introduced four intra cross-curricular technology themes as a general education experience from kindergarten to upper secondary school: (a) developing resources, processing materials, and making products; (b) converting, transmitting, and conserving forms of energy; (c) processing, transmitting, and controlling information; and (d) developing and conserving biological resources.

In addition, it was recognized that technolo-

gy instruction involves the following creative, problem-solving processes: identifying technological problems to be resolved; planning, designing, and communicating; manufacturing; and reflecting on technology and assessing the impact on the environment and society.

Ohnuma, Takahashi, Kasahara, and Yamazaki (1997) and Yamazaki et al. (2000) identified, through action research, the importance of three inter cross-curricular themes throughout formal, nonformal, and informal education: environmental study; foods, human health, and life skills; and mutual understanding between communities as well as international societies.

The Japanese Society of Technology Education (JSTE, 1999) also proposed two frameworks for providing opportunities in technology education as a general education for all, from kindergarten through upper secondary school. Four technology related curricular themes were identified as being closely associated with technology education: working with materials and processing technology; energy conversion technology; information, systems, and control technology; and bio-related technology.

We propose technological processing as a fifth curricular theme closely associated with technology education (see Figure 1).

Figure 1. Systems approach of technological problem solving in action



Table 1. Curriculum and Modules

First term (total of 6 class hours in grade 8)	
Module 1	Is the plug receptacle (socket) in your home really safe?
Module 2	Let's make an electrical extension lead.
Module 3	Let's develop an instruction sheet on how to use home electricity safely.
Second term (total of 18 class hours in grade 9)	
Module 4	Let's study electrical energy utilization in an earthquake disaster.
Module 5	Let's investigate wind, thermoelectric and atomic power stations in Joetsu district.
Module 6	Let's generate electricity by a hand-powered generator.
Module 7	Let's make a germanium radio without electric power.
Module 8	Let's make a radio with an emergency light generated by hand power.
Module 9	Let's consider how to use the radio to provide against contingencies.

Table 2. The Results of ANOVA Analysis in Each Comparison Between Pre and Post Self- Assessments

[1] Variables of capabilities about inter cross-curricular themes		
(3)	Safe management of natural resources and environmental preservation in home life, as a pupil makes all the members of own family understand and cooperate	A X C: 7.88** B: 2.85+
(4)	Using electrical appliances in a safety conscious way	A: 4.22*
(5)	Explanation about prevention of electrical disasters and safety regulations	C: 11.93**
(6)	Using electrical appliances with consciousness about environmental preservation	A: 6.16* B: 4.16*
(7)	Explanation about relationship between electricity and natural resources or environmental preservation	C: 4.19*
[2] Variables of capability of electricity in technology education		
(2)	Putting knowledge and skills, which the pupil studies in technology classroom, to practical use	C: 4.24*
(8)	Interest in assembling and repairing electrical appliances	C: 4.24*
(9)	Handling and good management of an electrical extension lead	C: 39.33**
(10)	Interest in the study of electricity	A X B: 4.79*
(11)	Understanding that it is dangerous to use electrical appliances inappropriately	A X C: 4.57*
[3] Variables of capability of portfolio study		
(12)	Bringing and using portfolio on electricity study for homework	Ns
(13)	Putting portfolio on electricity study to practical use	Ns
(14)	Writing and making portfolio to review in class	A: 8.77** B: 6.48**
(15)	Preparing study using portfolio	B X C: 4.02*
[4] Variables of capability of collaborative study with own family		
(1)	Collaborative study on portfolio in technology education with own family	A X B X C: 2.65 +
(16)	Review, with comments from own family about portfolio	C: 8.55**
(17)	Communication skills to make own family engage in the collaborative study	C: 5.59*

+ p < .10. * p < .05. ** p < .01.

Note 1:

Factor A: a comparison between a class of self-study and a class of collaborative study with pupil's family; Factor B: a comparison between higher, middle, and lower levels of achievements in technology education; Factor C: a comparison between pre and post self-assessments.

Note 2:

The number of pupils in the class of self-study was 38 (male 18, Female 20). The number of pupils in the class of collaborative study with the family was 38 (male 19, female 19).

Action Research

The Niigata and Ibaraki Prefectural Technology and Homemaking Teacher Research Associations, which are members of the All Japan Technology and Homemaking Teacher Research Association, cooperated in this action

research. Teachers of the Naoetsu and Chiyokawa Public Lower Secondary Schools also collaborated in this study from 1996 to 1999. Naoetsu Lower Secondary School is located on the west coast of Honshu, the Sea of Japan side of the island. Chiyokawa Lower Secondary

School is located in Ibaraki prefecture next to Tokyo's metropolitan district. Participants were Grade 8 and 9 pupils who were enrolled in a compulsory course in technology and home-making. The analysis of data was based on two Grade 8 classes in Naoetsu Lower Secondary School.

Curriculum and Modules

The curriculum and modules used within this study are shown in Table 1. Since the schools in this study were not authorized by the Ministry of Education Science, Sports and Culture of the Government of Japan as curricular experimental schools, the statutory course of study for lower secondary schools issued in 1989 (Ministry of Education Science, Sports and Culture, 1989) was adhered to in this study. Accordingly, we developed a school-based curriculum for use in the two schools.

As part of the study, we developed curriculum content links between the lower secondary school compulsory subject areas of technology and homemaking, and science. The technology and homemaking subject area requires pupils to study woodworking and home living at Grade 7, and electricity, food, and another three topics at Grades 8 to 9.

Another key aspect of the study was the production of portfolios of study by the pupils.

We proposed that the production and use of these portfolios would help pupils develop competence in both technological creative processes and collaborative study.

Quantitative Approach

This article reports on the quantitative and qualitative studies undertaken in Term 1. In order to investigate the effect of collaborative study with the pupils' families in the development of the curriculum, a three (A x B x C) factorial design research was carried out as part of the main research from October to November 1998 (see Table 2).

Factor A compared a self-study group and a collaborative study group with the pupils' families. Factor B compared higher, middle, and lower levels of pupil achievement in technology education. Factor C compared pre and post self-assessments. Pupils were pre and post self-assessed by means of a 6-point scale in each term.

Qualitative Approach

Pupils' descriptions and comments in their portfolios of study, and interviews with some pupils, were used as assessment devices. Participants were also observed in order to collect ethnographic data in real classroom situations. Pupils also had the opportunity to give their written evaluations within two weeks of finishing Term 1.

Figure 2. The average of self-assessment as compared with self-study and collaborative groups

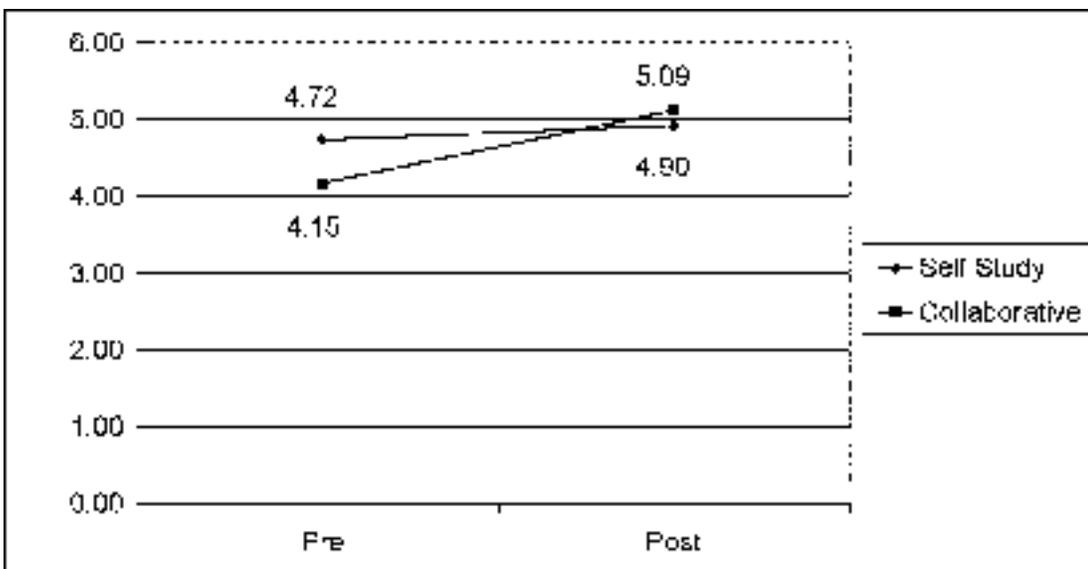


Table 3. Number of Pupils Who Commented in the Delayed Assessment on Electricity Study and How They Practiced in Real Life

Item	Family (n = 35)	Class (n = 35)
(1) Nothing	21	9
(2) About electric power saving	5	9
(3) Connected how to use electrical lead	4	6
(4) Do not act dangerously when using electricity	0	1
(5) Other	0	3
(6) Unknown	4	1
(7) No description	3	3

Table 4. Data of Comparison Between Pre and Post Self-Assessment in Case of Pupil W (Female)

Item	Pre	Post
(1) Underestimating that it is dangerous to use electrical appliances inappropriately	1	6
(2) Using electrical appliances in a safety-conscious way	1	5
(6) Using electrical appliances with consciousness of environmental preservation	1	3

The Curriculum Approach's Effects

Statistical Results

Because it is impossible to control experimental circumstances in a general, real classroom study, it is important to interpret and apply the data on pupils' pre assessment. The technology teacher Ohiwa, one of the authors, recognized that there were not large differences in his pupils' achievement, capability, and motivation. However, the authors, including the teacher, considered that there were some different ethnographical contexts between each class. Identifying the sociocultural context of the classroom is important in undertaking action research.

The results of the ANOVA analysis between pre and post self-assessments is shown in Table 2. The data for Item 3 shows that the interaction between A (self vs. collaborative study) x C (pre vs. post) was significant. The main effect of Factor B (a degree of achievement) has significant tendency. The simple effect of Factor A was significant. The simple effect of Factor C, with a degree of error at each level, has significant tendency. Therefore, the data highlights the effect of collaborative study involving the family.

The average of self-assessment as compared with self-study and collaborative groups in Item 3 is shown in Figure 2.

Portfolios, Cases, and Interviews

Item 1 in Table 3 shows a significance between self and collaborative study with the family. In the class where pupils undertook the collaborative study with their families, nine pupils described electric power saving. It is clear that the pupils also performed as a contact person and link between the class and family.

Case Studies

A comparison between pre and post self-assessments in the case of Pupil W (female) is shown in Table 4. She gained the highest scores in Item 11 in the post self-assessment though lowest in the pre self-assessment. In addition, she produced a very good portfolio entitled "Are My Home's Plug Receptacles Really Safe?" As part of her portfolio, she made an instruction manual, in the form of a cartoon comic strip, on how to safely use and manage electricity safely.

Data for Pupil F (female) are shown in Table 5. In her portfolio, she studied how handicapped or aged people safely use electrical appliances. In addition, she paid attention to how to use electricity, taking account of environmental preservation and prevention of disasters. In the interview with her, she answered that her father was very helpful in giving her useful information.

Table 6 shows a third case study involving Pupil W (female). The topic in her portfolio

Table 5. Data of Comparison Between Pre and Post Self-Assessment in Case of "Pupil F" (Female)

Item	Pre	Post
(9) Handling and managing an electrical extension and appropriately	2	6
(6) Using electrical appliances with consciousness of environmental preservation	4	6
(11) Bringing and using portfolio on electricity study for homework	4	6
(5) Explanation about prevention of electrical disasters and safety regulations	3	5

Table 6. Data of Comparison Between Pre and Post Self Assessment in Case of Pupil W (Female)

Item	Pre	Post
(6) Using electrical appliances with consciousness of environmental preservation	2	5
(3) Safe management of natural resources and environmental preservation in home life, as a pupil makes all the members of own family understand and cooperate	4	6
(5) Explanation about prevention of electrical disasters and safety regulations	1	3

was how to economize in the use of electric power. She investigated the methods of saving in the use of electric power for household lights, a refrigerator, televisions, a video player, an air conditioner and its remote controller, and a personal computer. She described the dangers of putting too much load on one electric outlet. She also noted how to use instruction manuals on electrical appliances and how they should be electrically grounded. In her interview, she was pleased that she undertook a beneficial collaborative study with her father in her homework because he was employed by an electricity company. The results show that both intra and inter cross-curricular approaches, together with collaborative study with the family, are very effective in developing trans-disciplinary competence.

What We Believe the Study Indicates

It is clear that the indigenous and school-based cross-curricular approaches in energy technology developed in this study are effective.

This study has shown some evidence of the educational benefits of pupils' collaborative

study with their families in energy technology.

The development of a portfolio is a very efficient study method in helping pupils develop cross-curricular competence.

Dr. Sadato Yamazaki is an associate professor in the Department of Learning Support, Joetsu University of Education, Japan. He is a member of the Omicron Field chapter of Epsilon Pi Tau.

Cyril King is an advisor in the South Eastern Education and Library Board, Belfast, United Kingdom. He is a Member-at-large of Epsilon Pi Tau.

Mika Shinde is a technology teacher in the Kanazawa Lower Secondary School, Kanazawa, Japan.

The late Osamu Ohiwa was a technology teacher in the Naoetsu Lower Secondary School, Joetsu, Japan.

Sohichiro Hirai is currently an inspector in the Ibaraki Regional Committee of Education.

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