A CASE STUDY OF A COLLABORATIVE PUSH-PULL MANUFACTURING LEARNING EXPERIENCE FOR INDUSTRIAL ENGINEERING AND ENGINEERING TECHNOLOGY MAJORS

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Abstract ? The authors conceived an interdisciplinary collaborative project for students enrolled in industrial quality control and simulation modeling analysis. This paper presents details on how this project was designed and implemented. The central theme of this learning activity included a comparative study of push and pull manufacturing systems. For students enrolled in the quality control course, the major challenge was to understand how these two systems affected quality outcomes. For students enrolled in the simulation modeling analysis course, the challenge was to create computer simulations of the two manufacturing systems and predict performance. The novel idea of this learning experience however was to bring students from these two courses together and engage in cooperative learning and problem solving. Student perceptions at the conclusion of this activity are also presented. The authors were pleased with the results and conclude that this was a positive learning experience for the students and worth replicating in other engineering and technology programs.

INTRODUCTION

During the decade of the 1990s and into the new millennium, interdisciplinary projects and teamwork have evolved as key topics in engineering and engineering technology curriculum. Interdisciplinary projects and team-based learning are promoted in several ways in engineering and technology at Northern Illinois University. In particular, during Summer 2002, the Dean's Office of the College of Engineering and Engineering Technology awarded us a grant to create and implement a cooperative learning experience for students enrolled in TECH 491 (Industrial quality control taught by Dr. Balamuralikrishna) and IENG 480 (Simulation modeling analysis taught by Dr. Phojanamongkolkij). The authors have prepared this paper to describe their joint efforts in designing and implementing a new integrated learning experience.

This interdepartmental collaborative activity implemented during the Fall 2002 semester focused on helping students from both courses achieve the learning objectives for their courses while simultaneously working together to achieve common team goals that were formulated by the instructors. The Technology majors had the task of conducting physical experiments that replicated typical push and pull manufacturing systems. The Industrial Engineering majors worked to create computer simulations of these systems. In the process, ideas such as Kanban [1] and the theory of constraints were also introduced [2]. The technology majors comprised of students specializing in manufacturing engineering technology as well as industrial technology. The reader should realize that the two classes met at different times of the week and this limitation continued to pose operational difficulties throughout the semester for both collaborating faculty and students. Recognizing this limitation from the outset, we decided to form larger teams thereby increasing the probability that there would be more interactions between students from both courses. Finer details are presented in later sections of the paper.

There is yet another rationale for this project. Real world engineering projects and problem solving require significant interaction between professionals from various disciplines. Yet, engineering and technology education continues to provide little or no opportunities for students to work in a team based environment or interact with students from disciplines outside their own. In an era where simultaneous engineering and integrated product and process development have become baseline philosophies for business and industry, it becomes important for educators to consider these factors in the pedagogical process. Engineers and technologists are natural allies, as their job functions require them to interact with one another constantly and significantly. One of the desired outcomes of this project was to provide a meaningful opportunity for students from different disciplines to interact and learn from one another.

THEORETICAL BASIS AND LEARNING OBJECTIVES

Traditional manufacturing systems are modeled as push systems. These are characterized by a management style that exhorts workers to produce more without much regard to the system as a whole. The push system essentially gives birth to

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a hidden factory inside the enterprise whose job is to repair, remedy or weed out defects. This system focuses more on local productivity as opposed to global optimization thus reducing the overall quality. The push system results in high inventories, high cost, low throughput, low employee morale, and poor quality.

On the other hand, the pull system of manufacturing has been hailed as the one deceptively simple aspect of the Japanese revolution in manufacturing using the tool of Kanban. In his book titled "The design of a factory with a future," author and researcher J.T. Black [1] professed that the pull system of manufacturing was a superior approach and would ultimately capture the minds of managers of production enterprises at all levels. Eliyahu Goldratt essentially employed the pull concept to devise a theory for production that is now popularly known as the theory of constraints [2],[3]. The pull system has paved the way for and is embodied in the much more familiar term that we know as cellular manufacturing [1]. Several progressive American companies have experienced success employing the pull concept while others are trying to make this change. Yet, a report on the status of manufacturing engineering education (SME's Manufacturing Education Plan Phase I) suggested that many of today's graduates are not aware of these concepts [4]. The aim of our collaborative project was to provide our College of Engineering and Engineering Technology (CEET) students with an opportunity to learn more about the principles and potential of the pull system and apply this knowledge to better design and plan production processes. More specifically through this project, the IENG 480 (Simulation modeling and analysis) students had the opportunity to use their engineering and programming skills to model two different cases of industrial production systems. The TECH 491(Industrial quality control) students had the opportunity to learn that management principles go a long way in promoting and fostering quality in industry. More importantly, all students involved had the opportunity to distinguish between local (sub-system) optimization and global (overall system) optimization, and their ramifications.

IMPLEMENTATION

Approximately seventy students were enrolled in TECH 491 (Industrial Quality Control) and IENG 480 (Simulation and Modeling Analysis) combined during Fall 2002 semester. Each class had approximately 35 students thereby providing an excellent starting point for the formation of student teams. The authors' decided to allocate four weeks during the mid-semester to conduct most of this collaborative activity. This timing was considered critical to the success of the project in that students would take some time to get to know each other and at the same time the last weeks of the semester are usually filled in with hectic activity from projects and homework from other courses. Students were informed that their performance in this collaborative activity would account for 30% of the final grade assigned. Students enrolled in the two classes were mutually excluded in the sense that no student was enrolled in both courses for the Fall 2002 semester.

During the first week of the Fall 2002 semester, the technology instructor rendered an introduction of the project in the industrial engineering class, while the industrial engineering instructor did the same in the technology class. This gesture on the faculty's part was designed to promote the collaborative spirit of the learning activity. The logistics and expectations of the project were communicated both orally and by presenting a carefully planned written description of the project available from the authors upon request. Student teams were formed based on an availability survey that was conducted during the first class meeting. We decided to have six teams with each team comprising of approximately twelve students split evenly between the two courses. Even though the students from the two courses were unable to meet formally as part of a regular class, they accepted the assignment challenge recognizing that alternate ways to communicate with each other was possible. In particular, we are referring to electronic means of communication.

During the first half of the semester, there was no collaborative activity. This is because students required this time to acquire a fundamental knowledge on quality management principles (technology students) and computer simulation (industrial engineering students) on their own, so that they all have the ability to understand and contribute in their own way towards the project. In addition, this also provided the time required for individuals to get to know each other. During this time, the Technology majors presented a poster session on total quality management that was open to the general public. Students from industrial engineering made efforts to attend this session and get to know their counterparts from Technology. Observations revealed that students were for the most part proactive in seeking to work together. The actual implementation of the project started during the second half of the semester. It was scheduled to take four weeks to complete all the physical experiments and computer simulations. The first two weeks were dedicated to the push system, while the last two weeks were dedicated to the pull system. Due to the schedule conflicts of both classes, the physical experiments of both push and pull systems were each carried out twice, once in the TECH 491 class and duplicated in the IENG 480 class. For the technology majors, the goal of the physical experiments was to observe how different the two systems were in terms of final throughput and performance. For the industrial engineering majors, the goal of the physical experiments was to observe and collect data to perform time studies for computer simulation.

System description, physical experimentation, and computer simulation of the push manufacturing system was introduced and carried out during the first phase (push system) of the project. The actual experiments were patterned after a pedagogical exercise originally conceived and publicized by the advanced integrated manufacturing (AIM) center, a collaborative effort between the University of Dayton and Sinclair Community College, both institutions based in the state of Ohio [5]. The technology instructor provided the system description and supervised the physical experiments in both classes. The physical experiment is designed to simulate the production and shipping operations that are a typical characteristic of manufacturing industries. The push system is characterized by operations each performing at their level of comfort with upstream operations not required to pay heed to what is going on downstream. For more precise details, the reader is advised to see the reference indicated above and [1]. A learning curve associated with this activity was imminent. Subsequently, a computer simulation of the push system was created by industrial engineering under the supervision of the faculty collaborator from engineering. The simulated results were compared with the actual data recorded during the physical experiment. Justifications of why the simulated results did not match with the actual data were also carried out in students' report. Engineering students accepted the responsibility to explain and discuss with their inter-departmental teams about the computer simulation of the push system.

The last two weeks of the project were dedicated to the pull manufacturing system. Both push and pull manufacturing systems had the same system layout and number/sequence of operations. The only difference is the fundamental philosophy and approach in operating each system. In the pull system, upstream operations were influenced to march to the tune and speed of downstream operations thereby limiting and maintaining an inventory level equal to one unit. For more details, the reader is advised to consult the references cited, particularly [1]. As a prelude to the pull system experiment, the engineering instructor explained the concept of "Kanban" using real world examples and learner-centered visually enhanced animations. The technology instructor was once again responsible for supervising all the physical experiments. The experiments were carried out and the data recorded and collected in a way similar to that involved with the push system. The Industrial engineering students under close supervision of their faculty generated computer simulations of the pull system. The programming aspect of the pull system was much more complex than the push system and students required more faculty guidance during this phase.

During this second phase of the project, students from both classes also had an opportunity to watch a documentary video titled "The Goal – How to version." This documentary movie helped students develop a finer understanding of a typical pull-based manufacturing system, which in the authors' opinion is particularly related to the theory of constraints. Details on how to procure this video are available from the Goldratt Institute, in particular their world wide web address is http://www.goldratt.com. The original pioneers of this learning experience recommended that a Harley-Davidson case study available on video be shown to the students between the push and pull experiments or simulations [5]. However, the authors were unable to procure this video and after considerable research, decided that "The Goal" video would serve as a good substitute. As part of their learning experience, Technology students were required to prepare a report contrasting push and pull systems and how each system worked for or to the detriment of quality in production. In addition, they were required to prepare a report on computer simulation with help from the engineering students. Engineering students were required to report their interpretations of the push and pull systems and elaborate on their programming efforts. Students were given an opportunity to learn from each other's reports and perspectives. Here again, the lack of a common meeting time for the two courses prevented us from having combined team presentations, a potentially rewarding learning experience.

RESULT & RECOMMENDATION

The faculty collaborators invested significant time and resources to complete the project. The physical experiments required intense planning, purchase of supplies, and high-level cooperation/coordination among student members. The computer simulations were fairly complex and conducted using a student version of ARENA. However, the complexity of programming the pull system required the use of a professional version of the software, which was limited in access under our current laboratory licensing agreement. However, we were able to overcome these shortcomings and conduct the learning experience as originally planned. The efforts were well placed and worthy considering how much the students enjoyed this learning experience. From the instructors viewpoint the students had to work diligently to complete all aspects of the project. At the completion of the project, the instructors' perception was that this collaborative activity provided a good platform for learning for students from both courses. The computer programs and reports submitted by the students were mostly excellent and provided significant proof of learning.

Through this project, the technology students witnessed the methods of computer simulation in process modeling and problem solving. We anticipate that the technology students would develop an appreciation for analytical approaches to problem solving and the programming skill levels of engineers. At the same time, we also expect that the engineering students would be able to experience how prediction and reality can differ and better appreciate the insight and problem solving ability of technologists. As part of the assessment and learning evaluation process, a survey was administered to the students at the end of the semester. This survey was only administered to technology students this time. Students were asked to retain anonymity while completing the survey in order to promote candid expression of views. A study of the thirty-three responses revealed that more than 85% of the students perceived that the project was a positive learning experience. Nearly 100% of the students indicated that they now understood the difference between push and pull manufacturing systems. Student reactions to the documentary video "The Goal" were overwhelmingly positive. Yet another interesting finding of this survey was that 75% of the students opined that more team projects would help them prepare better for succeeding in their future careers. However, students were desirous of having a common class meeting time to better collaborate with their peers from the other course. In conclusion, we urge engineering and technology educators to replicate this educational activity at their institutions and devise other interdisciplinary activities to provide enriched, collaborative learning experiences for engineering and technology students.

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