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Bringing Games into the Classroom in Teaching Quality Control*

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The increasing pressures from students, industry, government, and accreditation organizations demand a paradigm shift in engineering education to turn the focus of education from instruction to learning. In the course of Quality Control at the University of Manitoba, the concepts and principles of Total Quality Management (TQM) are usually taught through a series of lectures. Given the fact that few of the students have had any industrial experience, traditional lectures on this topic tend to be boring and ineffective. This work developed a game approach to simulate the dynamics between the customer and competitive manufacturing companies. Students were divided into one customer group and a few competitive manufacturing groups/companies producing maple leaf bookmarks. By role-taking and game playing, students gain a quick appreciation of four of the six main TQM concepts, i.e., management commitment, customer satisfaction, action of all, and continuous improvement. Based on students' feedback, this approach was proved to be effective in teaching abstract concepts and in giving students a certain level of real-world experience. The specific game designed in this work might be tailored for teaching other industrial engineering and manufacturing courses. The game method, as a general approach, might be further studied and developed for engineering education.

BACKGROUND

PARADIGM SHIFT IN EDUCATION. Today's engineering education in many schools and universities, more or less, still follows the traditional formal instruction and knowledge delivery approach. This traditional approach was referred as the *instruction paradigm* by Barr and Tagg [1], who noticed in 1995 an education paradigm shift from the traditional *instruction paradigm* to *learning paradigm* for the undergraduate education in all disciplines. The new *learning paradigm* promotes the theory that knowledge is not delivered but is constructed, created and 'gotten'. In the new paradigm, the center of education is learning, not instruction. The learning environments and learning process are cooperative, collaborative, and supportive. Faculties are primarily designers of learning methods and environments rather than primarily lecturers. The *learning paradigm*, however, does not prohibit lecturing. Lecturing becomes one of many possible methods, all evaluated on the basis of their ability to promote appropriate learning.

What constitutes appropriate learning is an ongoing research topic. It is generally believed, however, the assessment of learning in the cognitive domain should address the students' knowledge and skills of manipulating, applying, analyzing, synthesizing, and evaluating knowledge [2, 3]. Wiggins [4] even stated that the assessment of performance of exemplary tasks was the root of the so-called authentic assessment. Chisholm [5] confirmed that by saying 'while the knowledge base is important, it is of even greater importance that students understand and can use the knowledge and thus develop capacity.'

Falling in the traditional instruction paradigm, many of the engineering programs are still based on knowledge push with little or no time given to the development of understanding and application of knowledge [5]. Demands from the industry, government agencies, engineering accreditation boards, and students exert great pressure to engineering schools for a paradigm shift. In North America, accreditation boards such as CEAB and ABET recently put a strong emphasis on the design education in engineering to train students with the ability to manipulate, apply, analyze, synthesize, and evaluate the knowledge that they gain in the school [6]. In Europe [3], the overall observation was that 'the education of engineers is changing rapidly from the traditional chalk-and-talk approach to one that emphasizes understanding as well as acquisition of knowledge through an increasing involvement in project/problem-based activities.' Today in the era of information explosion and fast development of engineering disciplines, knowledge updates quickly. The capability of evaluating knowledge, acquiring knowledge, and applying knowledge becomes more and more important for future engineers. Engineer schools have to face the challenge to realize as soon as possible the shift from *instruction paradigm* to *learning paradigm*.

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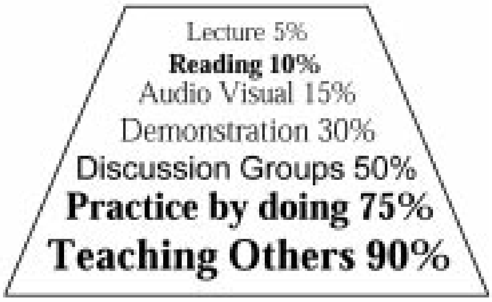


Fig. 1. Increasing student learning as a result of teaching technique [9, 11].

NONTRADITIONAL METHODS IN ENGINEERING EDUCATION

Kardos [7] stated that the most important condition for all learning is the interest of the learner. The traditional lecturing-receiving approach puts the instructor to the center of the learning environment, but the subjects of learning—the students—assume a passive role. Cameron [8] showed that students learnt more and were more highly motivated when they were actively, rather than passively, involved in the learning process. Research in education revealed that traditional lecturing resulted in the lowest retention of content material in comparison to the other methods of learning as shown in Fig. 1 [9, 10].

Among many nontraditional methods developed in the last few decades, the case-based method has been well known and relatively intensively studied as compared to other nontraditional methods [7, 12–18]. In the case-based methods, students are presented with well-designed, real-world or close-to-real-world industry situations for analysis, discussion and solutions. Such an approach enhances the interaction between students and faculties, stimulates students' interests, and motivates students for more in-depth learning [17]. The problem is that it is found difficult to design cases. American Society of Engineering Education (ASEE) archived many cases; interested readers can contact ASEE for those cases. Another similar method is the project/problem-based method. By working on a real-world engineering project/task, students enhance their cognitive abilities by solving problems, evaluating, criticizing and creating solutions; they also need to act independently, be self-motivating and cope flexibly with new situations. The project/problem method is currently used in many schools, for ecample, in course projects and capstone design courses, as a supplement to the mainstream traditional lecturing method.

In parallel with the case-based and the problem-based methods is the cooperative learning. Though cooperative learning can be independent from the former methods, they are most often mixed up with each other. The common form of cooperative learning is team learning. Michaelsen and Black [19] said that the team learning solution was to group students into small 'thinking teams' of four to six and to have them try out their application and analysis skills on each other in those teams. When interpreting new concepts and applying them to new situations, students can receive feedback on his/her understanding with other students instantly. Cameron [8] pointed out that the social side of learning was an important motivator as well. She said that we enjoyed a course because of our interactions with other students. The more meaningful these interactions, the more warmly we remember the course and its designer. One noteworthy point in cooperative learning is the group assessment as well as the individual accountability [20, 21].

Role-playing and workplace simulation is another nontraditional method in engineering education. Role-playing, that is, students are asked to play the role of key individuals in case situations, was thought to be able to provide variety to classroom teaching [2, 18]. Sullivan [22] simulated a real-world working place situation for the training of technical writing. Simpson [23] designed a manufacturing simulation by making paper airplanes to demonstrate the difference between craft production and mass production. Gibson [3] also documented that students were generally keen to become involved in role-play settings.

Recently, Thompson [6] documented the studio pedagogy for teaching engineering design. He found that students took ownership of their education and created their own individualized learning experience through this approach. They believe that studio pedagogy realigns engineering education with the future of engineering practice. Moreover, Chisholm [5] proposed the work-based learning approach, that is, students receive engineering education at the work place. Chisholm believed that the work-based learning could enhance lifespan learning and emotional intelligence (non-cognitive factors such as personality, creativity and innovation, and entrepreneurial factor).

Elshorbagy and Schönwetter [11] categorized teaching methods to three types, namely deductive instruction or traditional lecturing, discussion or facilitative instruction, and inductive instruction. Deductive instruction starts from lecturing abstract knowledge and then the application of the knowledge, which is the approach of traditional lecturing. Discussion instruction, similar to the case learning methodology [16], encourages student participation and in-class discussion to increase the interaction between the teacher and students. Inductive instruction reverses the process of deductive instruction, in that students are encouraged to find the knowledge by themselves by exploration, discussion, acting, and so on. This category may include problem-based method, role-playing and simulation, and studio pedagogy.

Elshorbagy and Schönwetter [11] believed that inductive instruction followed by deductive instruction had the potential to be an efficient way of teaching engineering. McKeachie [24] also proved, and Van Djik and Jochems [25] confirmed, that active learning methods generally resulted in greater retention of memory, superior problem-solving skills, more positive attitudes and higher motivation for future learning. Students like classrooms that involve active learning and teachers find such classes more enjoyable and less boring [26]. The common concern of teachers that they will not get enough material across in interactive lectures seems to be invalid as Van Djik and Jochems [25] demonstrated that the interactive approach was more beneficial compared to traditional lecturing. The interactive lecture increases student motivation, accommodates individual differences in their preferred ways of reaching understanding, increases learning interests, and also results in a better command of the same amount of knowledge as compared with the traditional lecturing approach.

THE COURSE OF QUALITY CONTROL

Quality Control (QC) is an important topic in manufacturing engineering. The QC course at the University of Manitoba covers many topics such as the concepts of quality control, Total Quality Management (TQM), statistical process control (SPC), acceptance sampling, design of experiments (DOE) and Taguchi's method, as well as concepts such as Six-Sigma and Poka-yoke. The first section to be taught was the TQM. TQM entails six main concepts, including management commitment, customer satisfaction, action of all, continuous improvement, supplier partnership, and performance measurement. These concepts are difficult to apprehend for people having no prior industrial experience. The students taking this course are in their final year of engineering. However, few of them have had real-world working experience in a manufacturing company. Lecturing to students with no prior experience on TQM will likely result in students' rote memorization, which will only be in their short memory [27].

To interest and motivate students in the learning of TQM, this work proposes a game approach. In this approach, students not only take roles but also participate in a simulated competitive manufacturing setting. The game was originally designed to give students a certain level of real-world experience to help them apprehend the textbook concepts. It is then found that it incorporates merits of the case-based method, problem-based method, cooperative learning, and role-playing and simulation. The following sections document in detail the game approach developed in the course of Quality Control, which was taught in the winder semester in 2002 from September to December at the University of Manitoba.

THE GAME APPROACH

If the traditional lecturing approach were to be used, TQM theories would be covered in five lectures with 50 minutes each. Instead of pure lecturing, a game approach was applied first to address mainly the first four concepts of TQM, namely, the management commitment, customer satisfaction, action of all, and continuous improvement. Three lectures were spent on the game and related discussions. Two traditional lectures cover the last two concepts of TQM on the supplier partnership and performance measurement. Therefore, the new approach by combining games and traditional lectures took the same amount of time as pure lecturing.

The entire game is comprised of three classes: the preparatory class, the game class, and the review class. The detailed description of the designed game is in Fig. 2; the description was handed out to each student in advance. The following sections will describe the activities and observations in each class.

Preparatory class

In a preparatory class before the game, 22 students in the class were divided into three manufacturing companies of 6 students each, and a customer group of four. Among the 22 students, only four of them have had industrial experience. These four students formed the customer group. The rest of the students were numbered 1, 2, and 3 in order according to their sitting positions in the classroom. Then all the 1s form a group; all the 2s are in one group, and 3s in one group. This approach was used to prevent close friends being in a group by assuming close friends tend to sit close to each other. These three groups are called manufacturing companies. The team division took about five minutes.

Students in manufacturing companies are then assigned each of five different roles: one CEO, one design engineer, two production engineers, one marketer, and one quality inspector. Each group submitted the record of each team member's role to the instructor. In the meantime, the customer group decided on which product they wanted the companies to produce. In this case, the game description only specifies 'a maple-leaf souvenir'. The customer group soon decided on the maple leaf bookmark because it was easy to make in class and simple enough for comparing the products of the three companies. The customer group also decided that \$1 was the price they would pay for a hand-made bookmark. They defined that such a bookmark should function as a bookmark, have maple-leaf patterns or symbols, be visually appealing, and be low in cost. After these decisions were made by the customer group, marketers of each company were allowed to interview the customer group to collect information, thus simulating the market analysis process. This process took about 15 minutes. Then the students were informed that

Game: Production of a maple leaf souvenir

September 20, 2002

Goal

Each team simulates a manufacturing company making a souvenir of a maple leaf. Each company strives to produce as many good quality products as possible to achieve the maximum profit.

Constraints

- The maple leaf should be made of simple and cheap materials such as paper, cardboard, plastic, wood, etc.
- Only human-powered tools are permitted in manufacturing.

Participants

One customer group and presumably 3~4 manufacturing companies participate in this game. Each company consists of a CEO, a designer, a marketing representative, a process and production engineer, and an inspector. The responsibilities of each role are as follows:

1. CEO: be responsible for all final decisions and chair his/her team
2. Marketer: be the liaison between customers and team members
3. Designer: be responsible for the design of the souvenir; all team members can participate in the design process.
4. Process and Production Engineer: be responsible for the manufacturing; the person can invite all team members to work together on the job.
5. Inspector: to determine which products to be rejected / reworked.

The customer group represents the body of customers. It is comprised by students, preferably, with industrial experience. For management purpose, it should have a chair, cashier, and recorder. The rest of the group can be quality evaluators to determine the payment for each batch the team receives. Collectively, the customer group should determine:

- What are you going to use the leaf for, e.g., bookmark, room decoration, air refresher, etc.?
- What price are you going to pay?
- What do you like it to be, e.g., shape, texture, weight, etc.?

The group should also

- Set a penalty / reward system for poor / good quality. For example, 10 cents more for good quality products and / or 10 cents less for poor quality products.
- Make bills to pay the companies
- Record how many products it purchased from each company and keep a record of cash flow.

It is assumed that the customer group sets no limit on the total amount of purchase. Though it might be rare, customers may return extremely poor quality products to companies. The customer group should exercise its power collectively, not individually, through a voting process. It should be fair to all companies. Unless interviewed by marketers, the customer group should keep all the decisions in confidence. Marketers from each company are encouraged to find out customers' decisions by interacting with the customer group.

Fig. 2. Description of the game.

the game would start a week from the preparatory class. Each manufacturing company should come up with a product design and a production and inspection strategy, prepare all the raw materials and tools, and be ready for production for the next class. After this, the companies stayed for the rest of the class for meetings. The customer group also stayed for tasks such as role assignment, design of special checks, determining the book keeping method, and deciding on quality evaluation criteria.

Students in the preparatory class showed a mixture of excitement and confusion. Questions such as who should prepare the raw material and tools were raised. It was observed that two groups, Group 1 and 3, had serious and long discussion with task distribution at the end of the meeting. Group 2 stayed only for a short while. When asked, they said they knew what to do.

Game class

A week later came the game class. At the beginning of the class, the instructor emphasized that the goal of the game was not to find out who would win or lose, and that if anyone got emotionally charged, certain measures would have to be

Procedure

All teams including the customers' group and manufacturing companies will form beforehand. The role of each person in a manufacturing company will be determined by the team members.

A preparation session will be carried out in the class, within which the customers' team should make all of the important decisions and companies can interact with the customers' team to obtain necessary information for the design. At the end of this session, each team should submit the names for each role to the instructor. The customer team should submit their important decisions to the instructor as well.

Then in about a week, the manufacturing company should come up with the design, the method to mass-produce it, all the necessary tools, raw materials, the inspection plan, and perhaps a detailed schedule of production. When back to the class, all companies should be ready for production. All the production activities should be carried out in class. Any pre-made products will not be accepted. The first round of production would be probably 10~15 minutes. The customers' team will determine the quality level and issue the payment to manufacturers accordingly. On occasions, the customers' group can stop purchasing from a company if the product quality of the company is too poor. The game will run 2~3 times. At the end of each round of game, summary of sales and estimation of each company's profit will be presented by the customers' team. All companies will have a few minutes of reflection and meeting on how to improve their competitiveness.

Summary

All companies should present answers to following questions in a review class.

1. Why did your company win (or why not)?
2. What could have been done better?
3. Who influences the product quality, and in what way(s)?

Page 2

Fig. 2. (*Continued*).

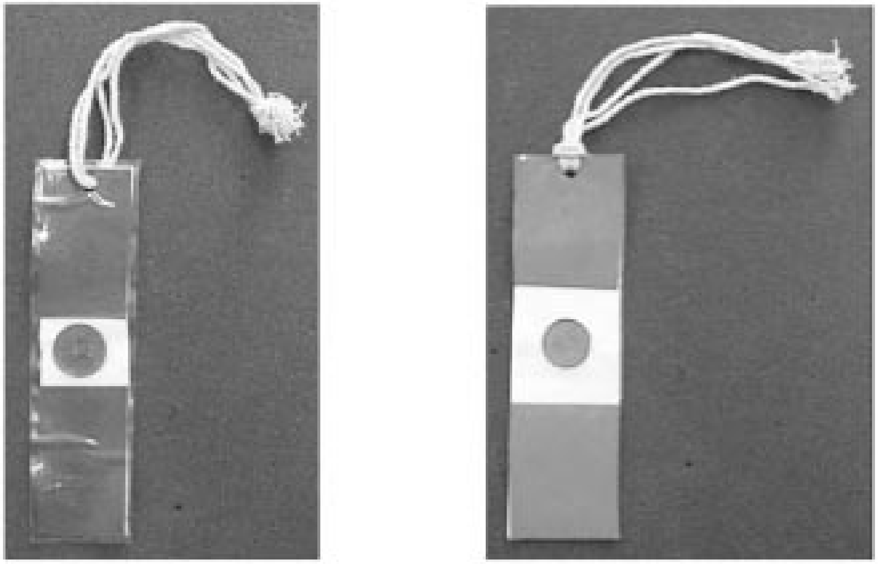
taken. Safety was also emphasized as tools such as scissors were used. After the announcement, the game started. The first round of the game lasted about 15 minutes. Then the manufacturing companies submitted their products to the customer group, who evaluated product quality and decided on a price they would pay for the products and issued a special 'check' to each company. The marketers of each company were allowed to talk to the customer group, seeking specific feedback on their products. Afterwards, the second round of the game started. After about 10 minutes, the game ended and customer evaluation process was repeated. The class ended on time.

Observations of round 1

Group 1 had an attractive yet simple product design (see Fig. 3). They used a Canadian penny, which has a pattern of two maple leaves. The coin was laid on a piece of white paper with two color stripes at each side. The assembly was laminated using MACtac^{TM} films. Then a hole was punched and a string was attached. The production of the design should be simple and quick. But Group 1 ran into a state of chaos at the beginning. In addition, team members sat in two right-angled rows, which made the communication and material transfer difficult. Members sat in random without consideration of the workflow. The bottleneck of the production was the cutting operation since there were many cuttings involved (cutting the color stripes, the bottom paper, and the laminate films). However, Group 1 had only one cutter, which slowed down the entire production process. The pressure of making more products in the given time caused hasty work by the cutter,

Table 1. Record of product value of each company (unit price times the number of products)

	Group 1	Group 2	Group 3
1st Round	\$0.94 *6 = \$5.64	\$0.75*4 = \$3	\$1.08*16 = \$17.28
2nd Round	\$1.11*17 = \$18.87	\$0*8 = \$0	\$1.05*22 = \$ 23.1
Total	\$24.51	\$3	\$40.38



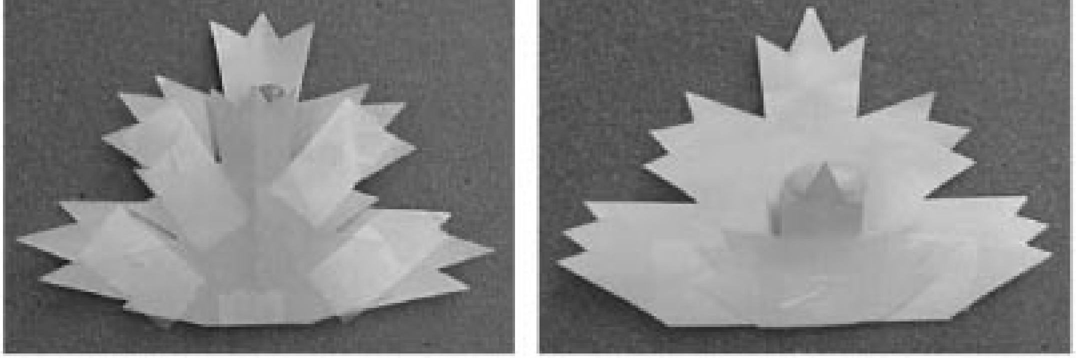
(a) (b)

Fig. 3. Products of Group 1: (a) a product from the first round; (b) a product from the second round.

which resulted in a high scrap ratio. The poor facilities planning and assembly line balancing were the major reasons for the low production rate in the first round (only 6, as shown in Table 1).

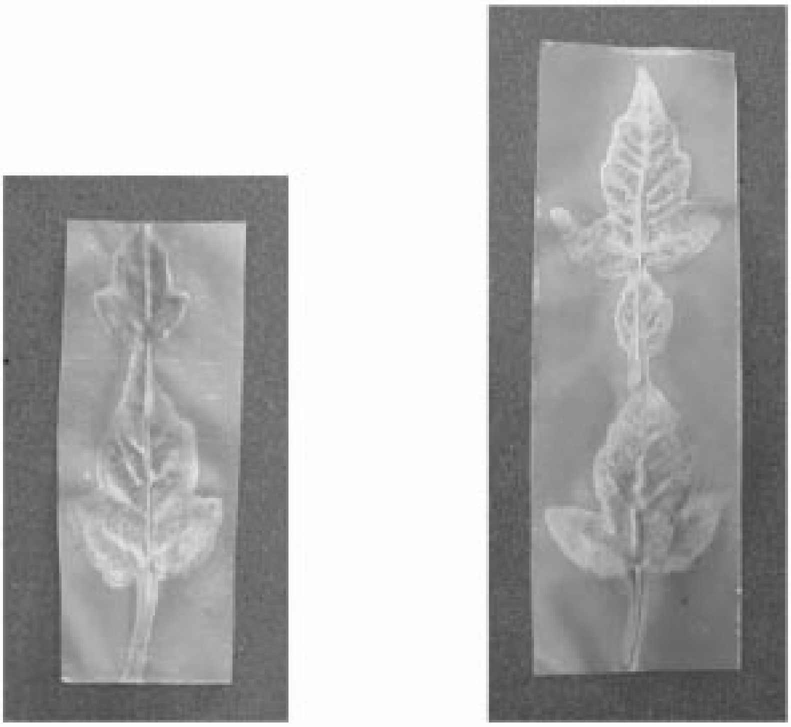
Group 2's product design consisted of two maple leaves (one overlaid on the other) with a jellybean inserted in between (see Fig. 4). This design failed to acknowledge the fact that the bookmark had to be functional as a bookmark, i.e. a flat surface would be required. It was found later in the review class that the company marketer did not even know they were making a bookmark. Secondly, the hand cutting of the maple leaf pattern might be time-consuming and inconsistent unless some templates were used. The tapes joining the two leaves were visually unappealing. While the game started, only three members of the company showed up. The CEO of the company was about 5 minutes late and the marketer 10 minutes late. The other member missed the class. The CEO brought with him some new materials, indicating that he had some other designs in mind, which was confirmed later. The CEO's design, however, was not adopted for probably two reasons. First, by being late he had lost the respect from the other team members. Second, some of the products had already been made. The miscommunication problem plagued Group 2 and the morale of the team was low. The production process was disorganized with too much waste and work in process (WIP). Three members were constantly in idle. Only 4 products were made during the first round.

Group 3's design was the simplest, in which two real maple leaves were laminated by using the MACtac^{TM} films (see Fig. 5). They reorganized the desks in a circle and streamlined the workflow. All the team members worked simultaneously and



(a) (b)

Fig. 4. Products of Group 2: (a) a product from the first round; (b) a product from the second round.



(a) (b)

Fig. 5. Products of Group 3: (a) a product from the first round; (b) a product from the second round.

no obvious idling was observed. The morale was high. They produced 16 bookmarks in the first round.

The customer group soon voted on the quality of each group's products. Using the baseline of $1, they complimented Group 3's design and the consistency of their product, and gave them a unit price of $1.08. They liked Group 1's design but noted that their products were of obviously different size (due to the cutting operation.) Thus Group1 only got a unit price of $0.94. The customer group also commented on the weakness of Group 2's design, such as the lumpy surface, the negative visual effect caused by the tape, and the inconsistency of the maple leaves. The instructor also went to each group reminding them of issues such as facilities planning, line balancing, design simplification, and so on.

Observations of round 2

In the second round, Group 1 improved their workflow and task distribution. They also changed the color of the stripes from dark brown to bright red to improve the product's esthetics. As a result, they were paid $1.11 for each product and 17 were produced in 10 minutes (as compared with 6 produced in 15 minutes in the first round.) Group 2 kept falling apart. They kept the old design. One member told me that the jellybean in the product was meant to be eaten first and then their bookmark would be flat. Unfortunately this argument was never conveyed to the customer group. Team members started to joke around. Group 3 accepted the comments from the customer's group by making a longer bookmark. However Group 3's quality inspector lowered the standard in order to produce more products. Some very poor quality products were sent to the customer at the end of the game, which brought down their overall quality rating and thus the unit price was reduced from $1.08 to $1.05. Group 3 even made a special bookmark as a marketing gift for the chair of the customer group, simulating some marketing measures utilized by industries, which was appreciated by the customer group.

Table 1 lists the value of each company, while assuming the manufacturing costs for the three companies are the same for simplicity. As one can see from Table 1, though Group 3 produced the maximum value of products, Group 1 had the fastest growth speed. Group 2's products were rejected because they didn't listen to the feedback of the customer group from the first round and no significant design improvement was made. Moreover, a member of Group 2 insulted the customer group.

Review class

In the following review class, all companies presented their answers to the three questions posted in the game description (Fig. 2).

1. Why did your company win (or why not)?
2. What could have been done better?
3. Who influences the product quality, and in what way(s)?

The customer group and the instructor also reviewed the game and presented their observations and comments on the game. The review class was fun since it was focused on their own story. It was also informative as most of the students articulated very well on issues such as management commitment, team work, and the impact of each role on the quality. For readers interested in the specific impact of each role, please refer to ref. [28]. The CEO of Group 2 reflected that they had learnt a lot from the game as well. He summarized the reasons why they lost the game, including lack of communication, low CEO commitment, poor process and production management, low morale, and insulting the customers. Some other things that students had learned were also presented, for ecample, the application of knowledge learned in other courses such as production management and facilities planning, methods of improving quality, and so on. Some students also expressed the desire to have more rounds.

The game significantly eased the lecturing on the topic of TQM. Among the six basic concepts of TQM including management commitment, customer satisfaction, actions of all, continuous improvement, supplier partnership, and process performance measurement, the first four were easily explained by referring to the game we had played. In the two ensuing lectures on TQM, the latter two concepts were explained in more detail [11]. The three game-related lectures and two formal lectures on TQM, in total, took exactly 5 classes—the same amount of time scheduled as if using the traditional lecturing approach.

Lecture on control charts using game data

Following the TQM philosophy, the control chart was the first statistical tool introduced. Control charts are often applied to measure the quality of an operation or a process, identify potential problems, and guide process improvement. It usually requires 25 subgroups of data with 4 observations in each subgroup. To relate the control charts with their 'industrial experience' gained in the game, the products produced by Group 3 were used. Unfortunately the total number of products available was too small. Thus in this case, each product was assumed to represent one subgroup and the range of variations within each subgroup had to be represented by a random number. Students constructed control charts to measure the length of the bookmarks made in the first round and the ones in the second round. With the assumed variation ranges, the control charts demonstrated that in the first round, Group 3's cutting operation (to get the exact length) was under control and the one in the second round was out of control, which confirmed the evaluation results of the customer group.

SURVEY RESULTS AND ANALYSIS

At the end of the course, a simple survey was handed to each student to measure the effect of the game approach on learning. The survey is shown in Fig. 6.

As shown in Fig. 7, 80% of students agreed or strongly agreed that the game approach was more effective in delivering the concepts with only 5% disagreed. 65% of students agreed or strongly agreed that the control chart exercise using the game data was useful and interesting with a higher percentage (20%) disagreeing. This might be due to the big group size in constructing the control charts. Since only two groups of game data (Group 3's products in Round 1 and 2) were

Questionnaire

1. For the game we played, do you think it is a more effective way in delivery the information than normal lecturing?

Strongly disagree Disagree Neutral Agree Strongly agree

2. Do you think the in-class control-chart exercise on the game we played is useful and interesting?

Strongly disagree Disagree Neutral Agree Strongly agree

3. For the game again, can you list at least two things each that you liked and didn't like? In which way do you think I can improve it?

4. Anything else you want to say to the instructor?

Fig. 6. Questionnaire for student feedback.

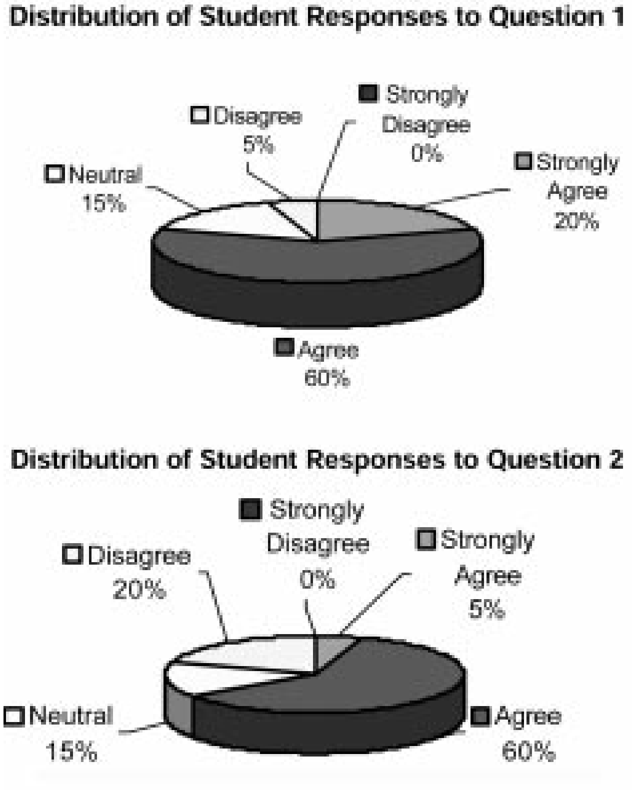


Fig. 7. Survey results for Question 1 and 2 (total responses: 20).

used, students were divided into two big groups of 11 each. In addition, only product data from Group 3 were used, which might have distanced members of other groups.

For Question 3, the students' comments are listed in Table 2. Some obviously identical comments are grouped into one comment (with a number attached at the end to indicate the number of occurrences). From students' comments, the 'hands-on experience' was highlighted. The class was thought of as 'fun' or 'interesting'. Many addressed that they learned a lot from the game. Students also enjoyed the enhanced interaction and teamwork with classmates. One student commented on the value of learning from 'mistakes'. In the 'Things I didn't like' column, the preparation of material and extra time spent on the project were complaints that appeared a number of times. This was likely due to the fact that most of the students had a busy schedule and the game was considered as 'extra'. Such a perception may be related to the scheme of student evaluation. The only student evaluation used in the course as related to the game was 'student participation'. Maybe more direct linkage between game participation and student evaluation needs to be established, so that the work will not be considered 'extra'. Moreover, to prepare materials and tools for the students beforehand might limit their creativity and also bring difficulties in managing the hardware for the department. Also students thought the game was too short and more rounds should be carried out. In the 'suggestion' column, it seems that finding ways to involve everybody more and to establish clearer rules needs to be considered.

Comments on Question 4 are listed below.

- *I enjoyed this course.*
- *I thought the class was well done and I enjoyed it. I feel that I learnt and understood the material.*
- *Good job.*
- *The bookmark game really stands out.*
- *This is a very interesting class, interactive, fun and interesting.*
- *We learned many applicable skills in an interesting manner.*
- *This course was taught and run in a relaxed manner.*
- *I think for this term that I learned the most from this class. I believe that the knowledge I gained from this course is valuable and I will use in my career.*
- *I really liked your approach towards learning.*

DISCUSSION

According to students' survey results, the game approach described in this work seems to be successful in motivating students, rendering them 'hands-on experience', and helping them to understand abstract concepts.

The game approach documented in this work shares some similarities with the case learning

Table 2. Comments for Question 3.

Things I liked	Things I didn't like	Suggestions
• Really good hands-on experience on quality control (4) • Helped me remember who is responsible for quality • Enjoyed the game and learnt a lot. • It broke up the tedium of lectures • Physical representation of material • Being interactive • Highlighted QC issues without direct lecture • See the entire flow and the associated QC issues • Helped understanding and appreciating some of the concepts • Encouraged creativity • Really made the material 'come to life' and a good way to get a grasp on concepts • To see the course information in action • Learned the effect of certain company roles and how they impact the other 'departments'. • It would be difficult to learn what I learned if my group was not as dysfunctional as it was. • It illustrated the concept well. • Helped everyone get to know each other (4) • Learned from others' ideas • Social interaction • Team work and atmosphere (2) • Open discussion • Fun/interesting (4)	• Should be another round. • It was done too quickly. • Not enough time (2) • Hard to get organized • Judges are subjective • Some person got upset and defensive when he lost • Materials were hard to find • Extra work outside of the classroom • Find materials by ourselves (2) • We have to buy materials.	• More clear and strictly enforced rules (2) • Smaller groups • More time for preparation • Some groups didn't take it seriously or didn't involve much. (3) • Provide basic tools and material and require that the groups use what they get. • No improvement is needed (2).

methodology with noticeable differences. Kardos [7] defined an engineering case as a written account of an engineering activity as it was actually carried out. In case learning methodology, the in-class discussion is the main format of lecturing. On the other hand, the game approach simulates a real-world working environment and students take specific real-life roles. Referring to Fig. 1, the game approach relates to the 'practice by doing' and 'teaching others' techniques while the case learning method relates to the 'discussion groups' technique. Notwithstanding the difference, both the game approach and the case learning approaches are interactive learning and inductive instruction methods. The game approach is similar to a problem-based method as both demand student groups design a solution. However, the game approach is different from the problem-based method, as the latter does not have to simulate an environment and does not require students taking roles. The problem in the game approach is not a single task; it involves the whole manufacturing business including product design, production control, marketing, and quality control. It is a simulation of the real-world manufacturing environment. The game approach could be considered as a role-playing and simulation method. However, it differs from the latter as the game is the key that links all the activities and roles. The game automatically organizes the simulation process, people and activities. From this regard, Simpson's simulation [23] is a game approach. It could also be considered as a cooperative learning approach from a broader perspective, because students work in a team to acquire knowledge, apply their skills, and receive feedbacks from other teams. The game approach differs from the commonly used cooperative learning approach as in the game approach multiple types of teams could be involved and interaction between teams is a must.

From the students' feedback, the game approach confirms the effectiveness of inductive instruction. The game designed in this course might be tailored for other manufacturing topics and courses even for the second and third year students, such as facilities planning, production management, assembly line balancing, and design for manufacturing/quality. The game approach might be used in general to bridge the gap between students' lack of experience and textbook content, and to change the format of lecturing from deductive to inductive instruction, or a combination of both.

The developed game approach, however, could be improved from the following perspectives:

1. After the first two rounds of competition and the review class, one more game can be played to allow the students apply what they learned into practice. Having understood their problems, Group 2 might be happy to have another chance and so positive performance improvement might be made. Group 1 might out-perform Group 3 as their growth rate is the highest in the second round. Group 3 would be further challenged if they would like to keep their leading position. The extra round of the game after reviewing and formal feedback should enclose the learning loop from acquiring the knowledge to applying the knowledge. The extra round should also produce more data for the construction of control charts. The drawback is that one more lecture hour would be needed.

2. Students participation in the game is only assessed through the participation mark, which accounts only 1~2% of their final mark. A more comprehensive assessment strategy could have been designed to address the students' organization, progress, level of efforts, and contribution [4, 29]. The individual accountability was not addresses in the evaluation either [20].
3. The manufacturing cost analysis and cost of quality might be incorporated into the game to address the performance measurement concept of TQM.

For a complete study, it would be ideal to conduct a comparison on students' learning results by using the game approach and the traditional lecturing approach on the same topic. The learning results could be evaluated by a traditional exam on knowledge, writing an essay on a related industry case to test their ability of knowledge analysis, synthesis, evaluation and application, or by asking them to do an exam on the topic after a few years to test their memory retention. Unfortunately there was no control group for such a comparison at the time.

To explain why Group 2 didn't function well in the game, the average GPA of the groups were compared. The average GPA of Group 2 was in fact higher than those of the other groups. Therefore the problems of Group 2 could not be attributed to its members being 'poor students.' One observation on Group 2 was that no female student was in that group while the other two groups had a mix of both sexes. This might be a factor causing the dysfunction of Group 2. Nevertheless, Group 2 provided examples of many common problems in industry, which enhanced learning and helped the instructor illustrating TQM concepts.

CONCLUSION

This work documents in detail a game played in the course of Quality Control at the University of Manitoba in teaching the concept of Total Quality Management (TQM). The game simulates the operation of manufacturing companies and the interaction of companies with customers and competitors. In the game, students are encouraged to obtain the knowledge by themselves in an interesting and real-world setting. Then students presented what they have learned to the class. Such a game approach integrates merits from the case-based method, project/problem-based method, cooperative learning, and role-playing and simulation method. Based on students' feedback, this approach was proved to be effective in teaching abstract concepts and in giving students a certain level of real-world experience. The specific game designed in this work might be tailored for teaching other industrial and manufacturing courses. The game method, as a general approach, might be further studied and developed for engineering education.

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REFERENCES

1. R. B. Barr, From teaching to learning—a new paradigm for undergraduate education, *Change*, (1995), pp. 13–25.
2. B. Cameron, Teaching effective thinking skills, in Cameron, B. and Lawall, M. eds, *Teaching at the University of Manitoba: A Handbook*, University Teaching Service, The University of Manitoba, Winnipeg, MB (1997) pp. 101–105.
3. I. S. Gibson, Assessment in Engineering Education—A European Perspective, *Int. J. Eng. Educ.*, **18**(4) 2002, pp. 465–471.
4. G. Wiggins, A true test: toward more authentic and equitable assessment, *Phi Delta Kappan*, (1989), pp. 703–713.
5. C. U. Chisholm, Critical Factors Relating to the Future Sustainability of Engineering Education, *Global Journal of Engineering Education*, **7**(1) 2003, pp. 29–38.
6. B. E. Thompson, Studio pedagogy for engineering design, *Int. J. Eng. Educ.*, **18**(1) 2002, pp. 39–49.
7. G. Kardos, Engineering cases in the classroom, in *National Conference on Engineering Case Studies*, (1979).
8. N. Cameron, Small groups, *The University of Manitoba UTS Newsletter*, (2000), pp. 1–3.
9. J. Biggs, *Teaching for Quality at University*, Society for Research into Higher Education, Buckingham, England, (1999).
10. R. Pike, *Creative Training Techniques Handbook, Tips, Tactics and How-to's for Delivering Effective Training*, Lakewood Books, Minneapolis, (1989).
11. A. Elshorbagy and D. J. Schönwetter, Engineering morphing: bridging the gap between classroom teaching and the engineering profession, *Int. J. Eng. Educ.*, **18**(3) 2002, pp. 295–300.
12. G. Kardos and C. O. Smith, On writing engineering cases, in *ASEE National Conference on Engineering Case Studies*, (1979).
13. G. Kardos and C. O. Smith, *Engineering Cases as Tools for Teaching Design Mechanical Engineering*, (1983).
14. R. W. Grossman, Encouraging critical thinking using the case study method and cooperative learning techniques, *J. on Excellence in College Teaching*, **5**(1) 1994, pp. 7–20.
15. J. M. Henderson, L. E. Bellman and B. J. Furman, A case for teaching engineering with cases, *Engineering Education*, (1983).

16. D. J. Kulonda, Case learning methodology in operations engineering, *J. Eng. Educ.*, (2001), pp. 299–303.
17. P. K. Raju and C. S. Sankar, Teaching real-world issues through case studies, *J. Eng. Educ.*, (1999), pp. 501–508.
18. S. Wassermann, *Introduction to Case Method Teaching: A Guide to the Galaxy*, Teachers College Press, Teachers College, Columbia University, New York, (1994).
19. L. K. Michaelsen and R. H. Black, *Building Learning Teams*, Growth Partners, Oklahoma City, (1994).
20. S. Kadel and J. Keehner, *Collaborative Learning: A Sourcebook for Higher Education*, National Center on Postsecondary Teaching, Learning and Assessment, Pennsylvania State University (1994).
21. L. K. Michaelsen, L. D. Fink and A. Kinight. Designing Effective Group Activities: Lessons for Classroom Teaching and Faculty Development, in DeZure, D. (ed.) *To Improve the Academy: Resources for Faculty, Instructional and Organizational Development*, New Forums Press, Stillwater, OK (1997), pp. 373–397.
22. F. J. Sullivan and R. Baren, Simulating the workplace in an engineering technology course: a rhetorical model, *J. Eng. Educ.*, (1997) pp. 279–284.
23. T. W. Simpson, Experiences with a hands-on activity to contrast craft production and mass production in the classroom, *Int. J. Eng. Educ.*, **19**(2) 2003, pp. 297–304.
24. W. J. McKeachie, *Teaching and Learning in the College Classroom: A Review of the Literature*, University of Michigan, Ann Arbor, USA, (1990).
25. L. A. Van Djik and W. M. G. Jochems, Changing a traditional lecturing approach into an interactive approach: effects of interrupting the monologue in lectures, *Int. J. Eng. Educ.*, **18**(3) 2002, pp. 275–284.
26. J. I. Shenker, S. A. Goss and D. A. Bernstein, Instructor's Resource Manual for Psychology, Houghton-Mifflin, Boston, (1996).
27. M. Svinicki. Practical Implications of Cognitive Theories. in New Directions for Teaching and Learning, Jossey-Bass Inc. (1991) pp. 27–37.
28. D. H. Besterfield, *Quality Control*, Prentice-Hall College Div., (2000).
29. M. Svinicki, *Four R's of Effective Evaluation*, University of Alberta Teaching and Learning Exchange, Edmonton, (1995), pp. 10–11.

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