# APPLICATIONS OF SOME MODERN MANAGEMENT TOOLS IN EDUCATION

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Since total quality management (TQM) (also known as the continuous improvement process) is used in industry,[1] it would be helpful for students to have an appreciation of what it involves before they graduate. One teaching strategy might be to give lectures on TQM theory, but such presentations often come across as being rather abstract and dull. Hence, it is difficult for the theory to demonstrate the real benefits of TQM. Descriptions of case studies also tend to be ineffective since the students are not actively involved, and the solution to a problem, once given, is often perceived as obvious.

An alternative approach is to introduce TQM indirectly by having students use the various TQM tools to address problems and issues that concern them. These tools are simple, quick, and fun to use, yet they reduce the time required to plan activities and accomplish goals. In addition, application of the tools promotes student creativity and participation, helps break down student-faculty barriers, and provides a mechanism for rapid feedback to the instructor (who acts as a facilitator for implementing the tools).

A variety of tools have been developed to help apply the underlying principles of TQM.[2,3] Some of these tools (*e.g.*, histograms, scatter diagrams, and control charts) are used to display and interpret numerical data and, hence, they can be introduced quite naturally with material on statistics and experimental design. Other management tools address "softer" issues such as organizing ideas, building consensus, and making decisions. In this paper, several examples of the second type of tools are presented (see Table 1), with emphasis on how to put them into practice.

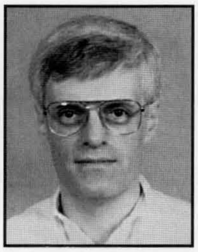

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**TABLE 1**
**Summary of Management Tools Described in this Paper**

| *Management Tool* | *Primary Function(s)* |
|---|---|
| Affinity Diagram | • To gather and organize ideas/opinions |
| Relations Diagram | • To establish the links among related items and identify the controlling factor(s) |
| Priority Matrix | • To decide on the most critical tasks/issues and plan the sequence of events |
| Deployment Chart | • To divide responsibilities among team members |
| Nominal Group Technique | • To rank preferences in a list of items |

## APPLICATIONS IN THE CLASSROOM

At the beginning of an elective course titled "Reaction Kinetics for Industrial Processes," the instructor asked the students "What are the goals of reactor modeling?" Specifically, they were asked to write, as quickly as possible (and silently), short phrases summarizing any ideas they had for the goals. The instructor encouraged student participation by emphasizing that all ideas are good ideas.

The students then formed teams (a total of 6-7 teams is optimal), grouped their ideas, and transferred each one to a 4x6 Post-It™ note (in large lettering, using a felt-tip pen). The notes were immediately placed in a random fashion on a large sheet of butcher paper attached to the wall. The students were permitted to read the notes as they were posted since this often sparks additional thoughts.

After many ideas had been posted (usually within 10-15 minutes), several students (one from each team) were given a few minutes to move the notes into groups that had common threads. This procedure, performed without discussion, was then repeated by other team members until everyone had been given a chance to sort the ideas. (Occasionally it was necessary to ask for clarification of a note's meaning, but there was never any critique of the ideas.) Next, the instructor asked the students to give each grouping a name (header card) that captured the essence of the ideas in that group. Some additional note movement occurred at this stage, i.e., if someone said "that idea doesn't fit there," they were told to go and move it. Anyone who disagreed was invited to move it again! The result is called an affinity diagram (see Figure 1).

The header cards were arranged to form a circle on the wall (with the notes placed outside the circle, next to the corresponding header card). Initially, a card was chosen (at random) and compared with each of the others, one at a time. For each comparison, the instructor posed the following question: "If we improve this item, does it improve the other item, or vice versa?" Then, an arrow was drawn from the cause to the effect (driver to outcome). For example, in considering the goals of reactor modeling, it was felt that

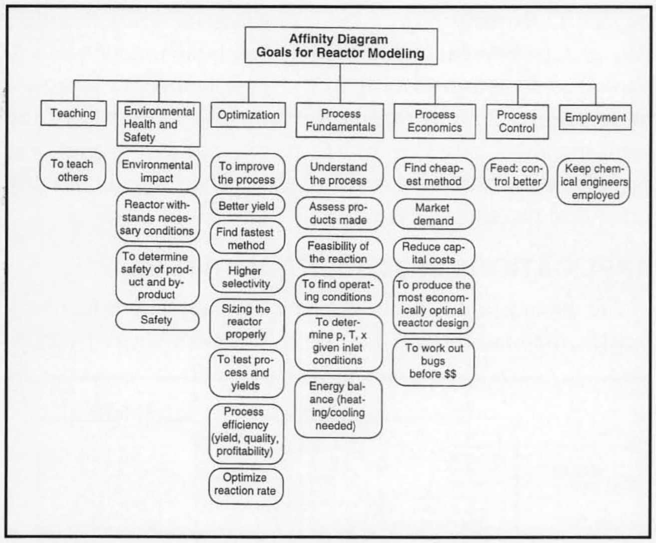


***Figure 1.*** *Illustrative example of an affinity diagram. The items in rectangles are header cards; individual ideas are in rounded boxes.*

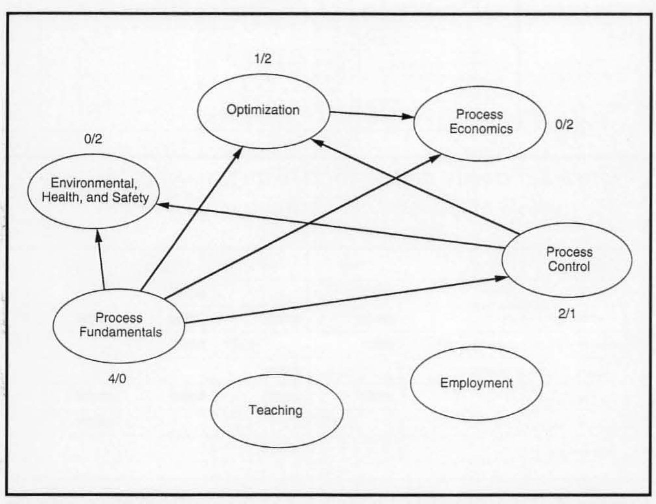


***Figure 2.*** *Relations diagram for "goals for reactor modeling." The header cards (in oval boxes) are from Figure 1. The arrows and numbers are explained in the text.*

***. . . management tools address "softer" issues such as organizing ideas, building consensus, and making decisions. . . . . examples . . . are presented with emphasis on how to put them into practice.***

better "Process Control" would lead to better "Environmental, Health, and Safety," rather than the reverse (see Figure 2).

Other arrows were established in a similar manner. In some cases, the cause-and-effect relationship was not clear and some discussion ensued. If a consensus could not be reached quickly on which item was the major influencer, no arrow was drawn. (In this situation, the relationship between the two items is usually not crucial.) In a few cases, no relationship between two cards was apparent, and when this occurred, again, no arrow was used. After the comparison procedure was completed for all the header cards, the total number of arrows out/in was written next to each one. The cards with more arrows going out are causes (drivers), whereas the cards with more arrows going in are effects (outcomes). The result is called a relations diagram.

For the example in Figure 2, "Process Economics" and "Environmental, Health, and Safety" had arrows entering but not leaving; hence, improving these items was regarded as the mission of modeling reactors. One heading (Process Fundamentals) only had arrows leaving; hence, it was regarded as the primary driver (*i.e.,* where effort should be focused in order to accomplish the mission). Copies of the two diagrams were distributed to the class and students were given a chance to comment and to present additional ideas.

Generation of Figures 1 and 2 took only about one hour of class time, yet it got the students involved in the material to be covered during the semester and it motivated them to learn that material. Furthermore, all the students (rather than just the ones with expressive personalities) felt comfortable making contributions because no one was "evaluated" for his or her comments. This approach had far more impact than a lecture because the students themselves came up with all the ideas, *i.e.,* it was is "their" diagram—the instructor did nothing but keep the procedure on track. At the same time, it showed them how two management tools could be used to answer a question efficiently and painlessly.

The same course involved a team project (with four people per team). The students indicated that they would like guidance on how to be effective and how to avoid conflict. Consequently, information was presented on

- *building an effective team (e.g., practicing team-building roles, dealing constructively with diverse opinions,[3] thinking "win-win,"[4] recognizing differences in people's personalities and accounting for them,[5] etc.)*
- *holding effective team meetings*
- *giving effective presentations*

- *using management tools to establish priorities and to get everyone to participate.*

Here, we will focus on the tools. After approximately two weeks had been allowed for initial technical reading on the assigned problem, the procedure for the affinity diagram was applied during a team meeting, using the question "What action items are needed to complete the project?" One slight difference from before was that the extent of grouping was kept to a minimum, although some ideas were rewritten to avoid duplication. Note that if students had prepared information in advance, they were asked to ignore it and just write down ideas "off the top of their head." (Otherwise there is a danger that one person will dominate and stifle the creativity of the team.) Next, a large 3x3 priority matrix of impact versus time was made on the wall (see Figure 3), and definitions were established (*e.g.,* what is meant by short, medium, and long term). The notes were placed randomly on the matrix and then moved around until a consensus was reached (*i.e.,* no more movement).

Sometimes there would be apparent disagreement regarding the position of an item, and when that occurred it was helpful to ask for clarification (*e.g.,* to see if the parties involved were interpreting it differently); often the solution was to split one action item into two or more items, which then fitted into different parts of the matrix. Occasionally, too many items were posted under High Impact. This situation was alleviated by asking "If we do this item, does it help the other item, or the reverse?" or "If this item isn't done, does it prevent us from making progress?"

Subsequently, tasks were allocated among team members using a deployment chart (see Figure 4). Low-priority items were disregarded or performed only after more critical items were completed. While team members volunteered for items they felt they could do well, the facilitator helped to ensure 1) that everyone got a blend of short-, medium- and long-term action items to help maintain an even workload, 2) that the high-impact items were not given to just one person, and 3) that all team members got some tasks with which they were comfortable. Some items required several or all team members and some teams agreed on specific deadlines for one or two critical items. The results were written up and circulated to the team (and to the instructor). Development of the priority matrix and deployment chart took only one to one and one-half hours per team, and it got everyone involved in the project at an early stage. The session demonstrated to both the undergraduate and graduate team members that everyone could make significant contributions to the project, and it helped motivate them to do so. As the work progressed, each team continued to evaluate its progress and, where necessary, prioritized in more detail (especially when time was running out).

There are many other places in the curriculum where management tools could be demonstrated to the students. For example, in an "Introduction to Chemical Engineering" course, an affinity diagram could be used to poll views on why students want to major in chemical engineering. Also, a relations diagram could show students the impact of safety issues in the plant or to help students decide which elective courses would be most beneficial to them in meeting their goals. Priority matrices could help students plan laboratory exercises or focus attention on critical unit operations in a design project.

In any of these applications, it is important to realize that while the instructor provides input on technical issues, his or her role as facilitator is solely to maintain focus, to keep the process on schedule, and to ensure that participation is balanced. In particular, the instructor should resist any temptation to direct the outcome since there is no "right answer." The important issue is that the results obtained from applying the tools truly reflect the consensus of opinion within that group. For example, writing the final report was regarded as a high-priority item by some teams but as a medium-priority item by others. Nevertheless, in each case, the team members believed in their result, and their report was completed successfully and on time. There are invariably several routes to success.

## APPLICATIONS IN STUDENT ACTIVITIES

The management tools can also be applied effectively outside the classroom. One example is with student societ-

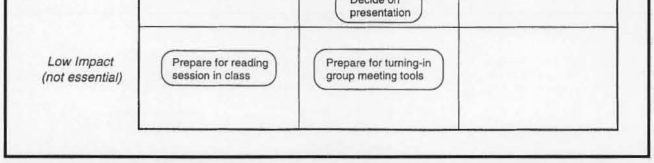


***Figure 3.*** *Priority matrix for a team project titled "Energetics of Adsorption Onto Metal Surfaces."*

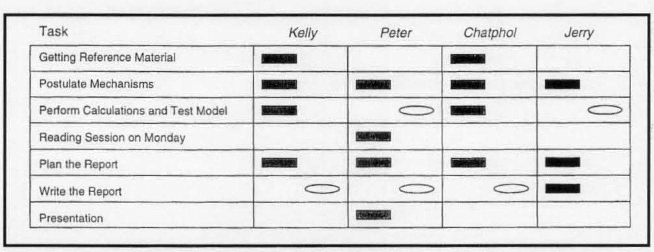


***Figure 4.*** *Deployment chart for the priority matrix shown in Figure 3. A shaded rectangle denotes responsibility and an oval rectangle denotes assistance.*

ies. In our ΩXE Honor Society we had previously initiated a lunchtime lecture series (together with an equivalent group from mechanical engineering), but the attendance had been poor and there had been some disagreement about topics (*e.g.,* more talks focusing on one discipline than the other). Consequently, the eight chapter officers used Post-It notes to come up with ideas for seminar topics, sorted them into n groups (as done for the affinity diagram), and asked their constituents (the undergraduates) to rank the ideas by voting for the n/3 they wanted the most (see Table 2). This is more expeditious than applying the full nominal group technique (NGT),[2] which would require each person to vote on every topic (giving n points to their top choice, n-1 points to the next choice, etc.).

The officers also sought information on how many seminars people would be interested in attending per semester. This motivated them to arrange seminars for the top three choices and it avoided any potential conflict over subject matter. It turned out that the top choices were "how to get a job," "what engineers do," and "computing." For these topics, the chapter officers made suggestions and agreed on both format and speakers. Then ΩXE held a preparative meeting where members used Post-It notes to come up with ideas for questions. The highest priority questions were also established by a variation of NGT: each student placed an adhesive color coding label next to the n/3 questions (out of n in total) they were most interested in, and those getting the largest number of labels were regarded as most important. The high-priority questions were then sent to the speakers so that they could present the most pertinent information.

**TABLE 2**
**Possible Topics for a Seminar Series**
*The numbers are the percentage of total votes (506) recorded for each topic. Each student had up to four votes.*

| % | Topic and *Examples* |
|---|---|
| 17.7 | How to Find a Job • *Interviewing skills; job-hunting skills; working with consulting firms; cooperative education/internships* |
| 14.2 | What Engineers Do • *Frontier areas of engineering/future directions; employee experiences from industry; consulting* |
| 11.9 | Computing • *Use of computers in engineering; how to use the computer laboratory; using your HP (beginning to advanced)* |
| 10.0 | Specific Areas of Study • *Nontraditional areas (materials); lasers; aeronautical/astronautical engineering; academic research topics* |
| 7.9 | Writing Reports |
| 7.5 | Information on Graduate School |
| 7.1 | Design Projects |
| 5.7 | Teamwork • *How engineers work together; total quality management* |
| 5.3 | Feedback • *Question/answer sessions with seniors; senior honors thesis* |
| 4.7 | Experimental Design/Statistics |
| 3.8 | Safety • *Safety and environmental concerns* |
| 2.4 | Another Lecture by Prof. Lienhard |
| 1.8 | Ethics |

The outcome has been highly successful seminars with attendance three to five times larger than before. The students feel that this is "their" seminar series and the officers make the seminar arrangements gladly. Moreover, at each seminar, feedback forms are handed out to attendees so that they can make comments, suggest improvements, etc. This information in turn helps the students prepare future activities that, hopefully, will be even more successful.

## APPLICATIONS IN THE DEPARTMENT

An additional way that students can see TQM in action is for faculty and departments to practice it. Examples could include getting feedback from advisees and alumni (*e.g.,* to see if we are providing what the students really need) and establishing directives for offerings in both electives and continuing education.

At the departmental level, the management tools can be applied to operations that do not involve the students directly, *e.g.,* establishing vision-mission goals for the department and, in turn, setting priorities for faculty hiring, allocating resources and service tasks, and developing criteria/measurements of success. In addition, the tools can help identify more effective methods for recruiting the top graduate students and interfacing with (local) industry. For the staff, one can set up "quality circles" where the tools are used to pinpoint systemic problems and help find ways to streamline them.[6]

In most departments, there will be some "low hanging fruit" that can provide relatively short-term successes and serve to illustrate the benefits of the approach. However, application of the tools at the departmental level will fail unless there is a clear commitment from the administration (*e.g.,* the Dean and the Chairperson) to embrace the results of the TQM process;[7] if people go through the process only to have administrators manipulate the results, it is even more detrimental to morale than not doing it at all. Conversely, if the Chairperson and the facilitator are trustworthy and do not have any vested interests, application of the tools could make a significant contribution to the success of a department.

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