Simulation and Other Tools to Enhance Student Learning

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Abstract

Simulations in various forms have been observed to be promising vehicles to enhance and stimulate student interest and learning. Since students exhibit different learning styles, and needs, they might react differently to simulation experiences. At the same time the conditions for application of simulations might be different for distance students compared to students in a traditional on-campus classroom protocol. The authors discuss the various decisions associated with the design and construction of appropriate learning environments based on their experience with a broad range of courses and simulation tools in Engineering Management. The efficacy of these various approaches is assessed by student surveys and instructor observations with respect to student learning styles and classroom protocols.

Introduction

There is a growing need to enhance student learning effectiveness and efficiency in engineering education. Even though technological knowledge has been rapidly increasing, competition for students among universities has not allowed for expansion of the curricula. In fact, in many universities, the required load for graduation has been decreasing. One way to handle this dilemma is to focus more on the theory and fundamental issues in each class. This forces employers to do some of the training that was performed within the engineering schools[1]. Another approach is to find ways to provide the students more learning in less time through more effective and efficient engineering programs. One way to provide this higher level of learning is by using additional tools and methods. Simulation is a promising educational tool that might help improve the learning environment.

Another trend in engineering education is an increase in the diversity of the student body. Due to explicit efforts to recruit underrepresented minorities into engineering, the needs for life-long learning, and the increasing participation of non-traditional students in the engineering programs, the students enrolled in any one class are more likely to have a wide range of knowledge, experience and backgrounds. These students are likely to have different learning styles, and different perception regarding many of the issues introduced in the classes. This is particularly true in engineering management classes since the students generally also have different engineering backgrounds and life experiences. Simulation has the potential of providing a more robust environment for learning and to provide common experiences to the students that can facilitate further learning as a class.

The power of simulation

Simulation can provide a number of advantages to an engineering management class. It can provide experiential learning for the students in areas in which they might not have any experience. It can provide a common base of experience to all the students in a class, even if they had not prior exposure to an area such as manufacturing. This helps the students understand how quality engineering tools can be introduced into the manufacturing process. Simulations can provide another channel of learning that can motivate students since it is more realistic, applied and fun[2]. In addition it can be more personalized, since the students can quickly see the results of their decisions. This is particularly important for students that are not adequately motivated through the standard lecturing experiences. In addition, simulation provides a "hands-on" approach that appeals to many students and therefore provides increased learning. The psychology of learning suggests that the more senses that are involved in the learning experience, the greater the probability that the fundamental concepts will be captured in long term memory, or "learned"[3].

Learning styles

The learning styles are personally preferred ways of dealing with information and experiences. This concept has become an educational tool with applications in engineering education. Felder and Solomon have developed tools specifically for engineering educators that have been widely utilized[4]. Knowing how a student likes to learn can assist the instructor in developing procedures to instruct these individuals and make the learning process effective.

Situation

Engineering management attracts a great diversity of students. While some have no work experience, others have a considerable amount. Some have taken numerous courses in Engineering Management while others might have recently transferred from another engineering program and have little background in the discipline. Many of the classes include both graduate and undergraduate students. Most are native English speakers, while others are international students with difficulties communicating in English. Some are on-campus students that are taking traditional courses, while others are taking them through distance education channels. This poses a challenge to the instructors, since their educational and personal backgrounds are very different and these differences should be considered in the design of the class environment.

Luckily, many of the engineering management programs have access to synchronous and asynchronous multi-media capabilities. This enables the instructor to provide new ways to deal with this challenge by presenting information and the learning experiences through different channels. This paper discusses two ways of using simulation in engineering management classes. The first approach is asynchronous, in which students in two quality engineering courses use simulation to learn various concepts at their own pace outside of class. The second approach uses synchronous simulation in an industrial marketing course in which student teams simultaneously compete with each other in a product development process.

Simulation in quality education

Herein we give a brief discussion of several simulations and their impact on the relevant Engineering Management (EMgt) courses.

EMgt-375: Total Quality Management: Total quality management is required of all quality majors in the engineering management department, and is a popular technical elective course for other students in engineering management, mechanical and electrical engineering, computer science and other programs on campus. In addition, this course is a part of the quality engineering specialty track in our System Engineering (http://web.umr.edu/~syseng/) MS program, which is offered worldwide to employees of the Boeing Company and other interested students.

Professor Ragsdell has developed and taught this course since 1989 at UMR[5]. It is based on thirty plus years of interaction with industrial leaders in the US and Japan, such as General Motors, Ford, Xerox, Nissan, Nippon Denso, and government leaders in Missouri[6], the US and Asia, and in healthcare organizations[7]. The course has been given using every conceivable format. In fall 1999 the course was reorganized to a two lecture/one lab period per week format. A web site, which contains all handout material (course schedule, lab assignments, publications, etc.), lecture slides, and grade book, was created for the course. One of the major objectives of this course is an understanding of variation propagation, and its effect on product performance in the hand of the customer. In an effort to assist students to learn variation concepts, several of the laboratory assignments require the use of a virtual calculator, which is provided in a multi-media learning environment (Total Quality Management: A Multi-media Learning Environment) currently available to students on compact disks.

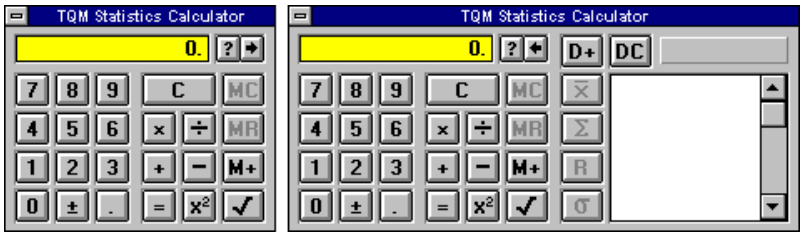


FIGURE 1: VIRTUAL CALCULATOR

The calculator is helpful to student learning teams as they complete the "ruler experiment" assignment.

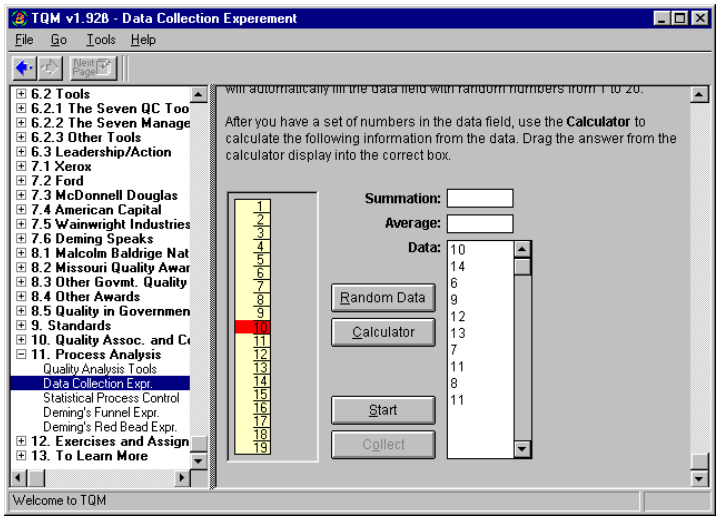


FIGURE 2: RULER EXPERIMENT

The goal of the ruler experiment is to demonstrate common and special causes of variation, and to give students the opportunity to deal with each type in an organized fashion. The assignment reads as follows:

> This exercise has three objectives: team building, data collection, and examination of the implications of the old and new styles of management. Assign the following duties to team members: 1. dropper, 2. catcher, 3. inspector/recorder, 4. manager, 5. dropper foreman, 6. catcher foreman.
> **Phase One Ground Rules:** Droppers drop the yardstick with their eyes closed. Dropper foremen tell the dropper when to drop. Catchers catch the yardstick with their eyes closed. Catcher foremen tell the catcher when to catch. The inspector/recorder inspects and records the point on the ruler where the catcher catches. The manager's role is to tell everyone what to do; to condemn "off-target" performance and praise "on-target" performance. Otherwise, the manager does nothing! Catcher and dropper are not allowed to communicate with anyone except their foreman; certainly not each other. Foremen can speak to their respective workers, the inspector/recorder, but not each other. They must go through the manager to send messages to each other. Proper protocol must be used at all times. The ruler is held by the dropper and the catcher's hand is placed in the initial catching range. The dropper foreman tells the dropper to drop the ruler. The catcher foreman tells the catcher when to catch in order to hit the target. The inspector/recorder observes and records the results.
> **Phase Two Ground Rules:** Same as Phase One, but dropper and catcher open eyes and can communicate with anyone they choose. Foremen do as the dropper and catcher say. Manager goes home and remaining members work as a team to complete task in most efficient and reliable fashion, so as to produce on-target performance with minimum variation.
> **Assignment:** As a team collect 50 data points using Phase One and 50 data points using Phase Two ground rules. Assume a target of 20 inches and use the catcher / dropper protocol discussed in class. Hint: record all information that will help you to see random and assignable causes in the analysis assignments to come.

On-campus students are allowed to use a physical ruler or to use the virtual ruler in Total Quality Management: A Multi-media Learning Environment. Remote students typically use the virtual ruler, and must improvise (recruit family members or friends) in order to complete the assignment with the required team approach.

EMgt-376/475: Quality Engineering: Quality Engineering is offered in two versions, one designed as a capstone design experience for undergraduate quality majors in the department (EMgt-376), and a more advance version designed primarily for MS and Ph.D. students in Mechanical and Electrical Engineering, and Engineering Management. The advanced version

was offered in spring 2002 to a class of students on campus, to remote students over the Internet, and to a class of Army captains at Fort Leonard Wood. These courses are also being offered in the same formats in winter semester 2003. Live lectures were given three times per week, and were available on the Internet using live streaming video or later from the course webpage.

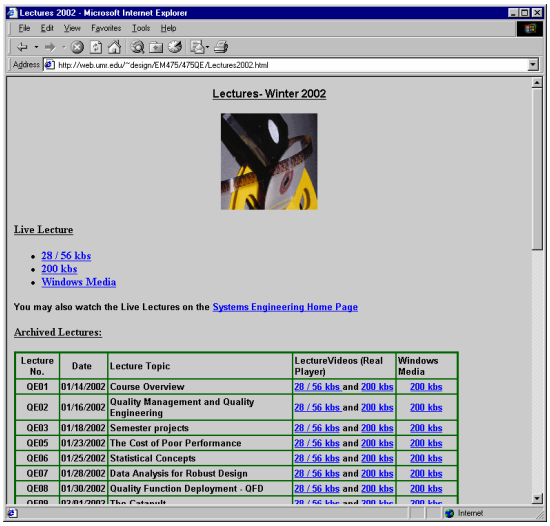


FIGURE 3: QUALITY ENGINEERING LECTURES

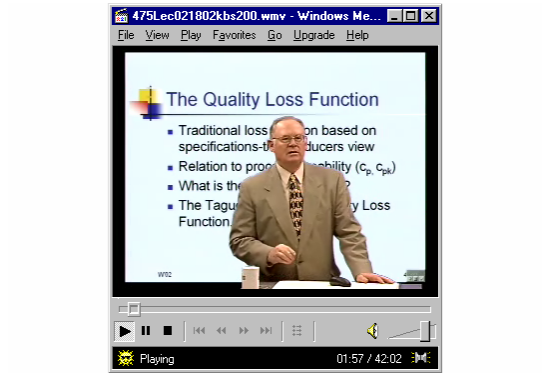


FIGURE 4: EXAMPLE VIDEO LECTURE

All lecture slides and other materials are available to students in advance on the course webpage. All students in the quality engineering courses must complete a semester project. In spring 2002, students selected one of four project assignments, except for one distance student group that decided to work on a work related project. The students choose one of the following projects: catapult, Wheatstone bridge, automotive disk brake system, or design of a cool drink. Students that chose the catapult or disk brake system projects were provided with simulations that facilitated experimentation. We briefly describe one of the simulations here.

The Catapult: The Catapult is a device designed to throw a projectile to reliably hit a distant target. The key word here is "reliably hit." A good discussion of the mechanics of the catapult

is given by Fowlkes and Creveling[8]. A simulation of the catapult, as shown in Figure 5 is provided to students.

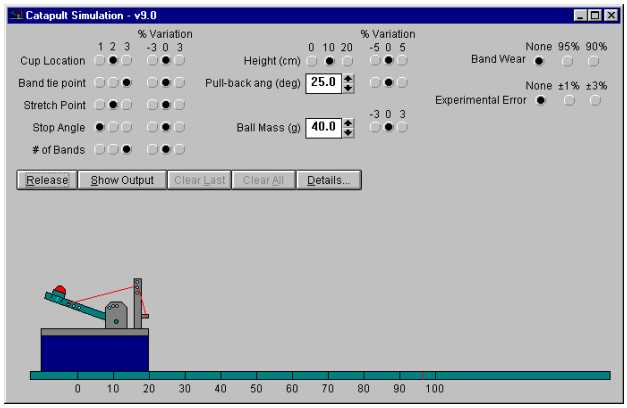


FIGURE 5: THE CATAPULT

The simulation provides a fully functional catapult with a wide range of selectable parameters, and a resulting wide range of potential target locations. Ease of use and safety are two major advantages of the simulation. In addition, the simulation package contains several additional useful features. Each time the catapult is fired the settings and results are displayed in tabular form by selecting the output button.

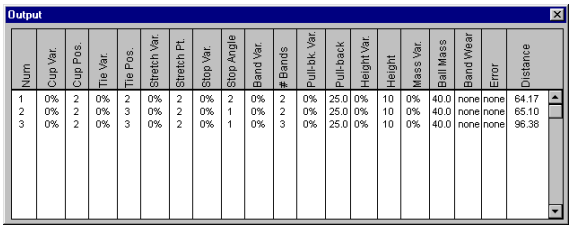
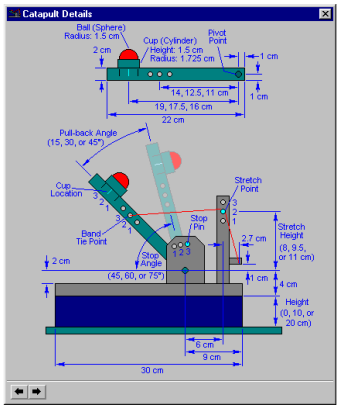


FIGURE 6: OUTPUT WINDOW

The details button gives the free body diagrams for the catapult system, and all equations of motion for the catapult system elements and the projectile.



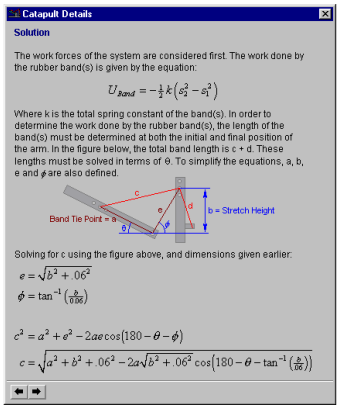


FIGURE 7: FREE BODY DIAGRAM AND EQUATIONS OF MOTION

Students find the catapult simulator fun to use, and they typically begin to use it with little or no instruction or encouragement. The simulator is designed to demonstrate the effects of variation propagation. Manufacturing and operational variation can easily be demonstrated. The value of this simulator as a tool to encourage students to experience "real" quality engineering problems can not be overstated.

An Experiment

EMgt-475 has now reached a degree of maturity, which allows experiments in delivery. Many forms of delivery style have been attempted over the last decade. In Spring 2002 a class of 20 Army officers at Fort Leonard Wood enrolled in an accelerated 8-week version of the course (same course as on-campus, but faster pace), which is an elective in their MS program. Typically, UMR classes are delivered in person by senior faculty at Fort Leonard Wood. A normal class involves the instructor lecturing for most, if not all, of the class period. Students ask questions in class, but have little time for small group discussion, or one-on-one discussions with the instructor. Students work on homework, read the book and other assigned material, and work on laboratory assignments and the semester project in small groups (learning teams), or individually. We do not have space to discuss the learning team concept here, but interested readers can learn more at the course webpage. Ragsdell decided to ask the class to consider a rather radical experiment in delivery style at the first class meeting. The proposal involved turning the course style upside down. "Let us work together (the class was divided into learning teams, which were assigned to work together on laboratory assignments and the semester project) in class on the labs and the semester project." Students were then assigned to view the lectures in video format using RealPlayer or Windows Media Player, and to view the lectures on Blackboard using animated slides via Shockwave with coordinated audio. Each student was assigned to keep a log of his or her experience with Blackboard and the streaming video material. One of the semester laboratory assignments was to review each of these delivery formats. Two surveys of student opinion were conducted using Blackboard, which allowed anonymous responses. The students were asked to respond to fifteen statements with one of five responses; strongly agree, agree, neutral, disagree, or strongly disagree. The fifteen statements are:

1. I find the content of this course to be of interest.
2. I enjoy the discussion style of this course.
3. I find the instructor to be knowledgeable.
4. I find that working with the instructor in class on the project is useful.
5. I found the instructor to be open to questions and discussion.
6. I find that working with the instructor in class on the project is useful.
7. I found the material provided on the course webpage to be helpful.
8. The lecture videos on the web are helpful.
9. The blackboard presentation of this course is helpful.
10. I prefer the lecture videos to the blackboard (shockwave) presentation.
11. I prefer the blackboard (shockwave) presentation to the lecture videos.
12. I would prefer a traditional presentation, where the instructor lectures, and lab and project work is done outside the class time.

13. I think this course will help me after my military career.
14. I think this course will help me in my future military career.
15. The instructor appears interested in students and this course.

Twenty students responded to this opinion survey, which was given on 19 March 2002. A summary of the responses is given in Figure 8.

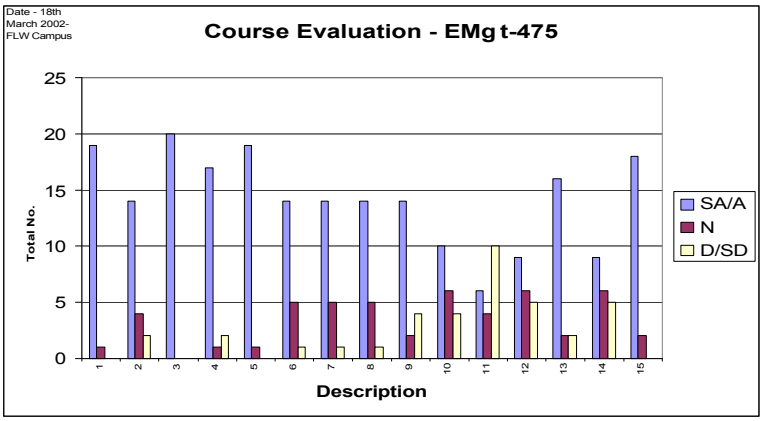


FIGURE 8: STUDENT OPINION SURVEY AT FLW, 19 MARCH 2002

From these responses we see that a majority of the students found the course to be interesting and the instructor knowledgeable, enjoyed the discussion style of the course, and generally found the materials provided over the web to be useful. Let us examine the responses to items 12 and 10 and 11 more carefully. We see from the results that 9 students agree or strongly agree that they would prefer a traditional presentation of the course. This means that 11 students either don't care or would not prefer a traditional presentation of the course! The responses to item 10 and 11 show that exactly half of the class preferred the lecture videos to the blackboard presentation of the course. Comments in class suggested that the preference for the videos was much stronger, but many students said that the choices given in the opinion survey were complicated by the slow modems available to them during the course. That is, they said they may have responded differently if a high speed line had been available on a 24/7 basis.
We then wondered if these opinions might be correlated to personality type. All students were asked to take the Myers-Briggs Personality Type on-line test[9], and another survey (exactly the same questions) was given on 18 April 2002, with the exception that each respondent was asked to provide their Myers-Briggs Personality Type. This time only 17 of the 20 students responded. One student failed to report his/her Myers-Briggs Personality Type. A summary of the student responses is given in Figure 9.

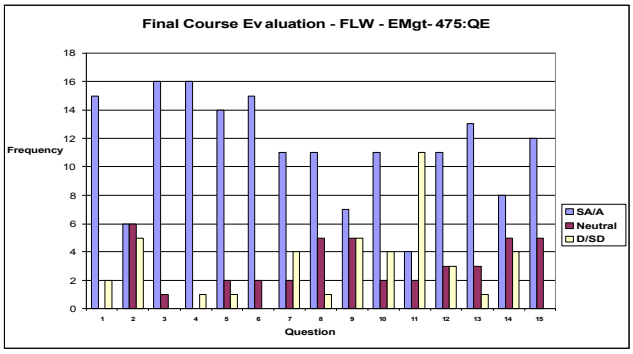


FIGURE 9: STUDENT OPINION SURVEY AT FLW, 18 APRIL 2002

The results are generally the same as before except that one student has developed doubt concerning the knowledge of the instructor, and the preference for the video lectures over the blackboard presentation is now much more pronounced. Be aware that this survey was completed on the last day of class, which was also the day that all students gave their final oral presentation of the semester project, and handed in their written project reports. In his class there were 5 ENTJ's and 5 INTJ's. The results show that 100% of the ENTJ's felt that working with the instructor in class on the project was useful (item 6), whereas only 60% of the INTJ's had this opinion (40% were neutral). We also observe that 80% of the INTJ's would prefer a traditional presentation, but only 40% of the ENTJ's had this opinion. Similar experiments are being conducted in winter 2003.

Simulation in marketing

The Palmtop simulation program was originally developed to help recruit high school students into engineering management[10] but it is also used in engineering marketing classes to highlight the value of marketing. The simulation model provides an enjoyable experience for students without business background to make decisions related to the new product innovation process and highlights the usefulness of business skills for engineers. The program was created to allow students to experience some of the issues of decision making in a high technology company. They experience the importance of business issues such as marketing, management, finance and engineering economics within a team environment. The students are formed into teams that compete with each other to develop the most profitable palmtop computer business. As they allocate resources to design and produce the palmtop computer they learn the importance of designing a product line that meets customer needs while maintaining profitability. In the simulation there are two types of customers that have different preferences for the product characteristics. The first is the elite customer that wants a powerful reliable and good looking product. The other is the basic customer that wants a low cost reliable product. This exercise is unstructured, since the teams are not sure how to find the best solution nor what methods they should use. If the teams choose to acquire the marketing information and react to it, they can shape their products to the specific needs of one of the customer groups. Otherwise they make their judgment based on their own values and hope the customers respond favorably. They work in teams to make these decisions, compare their results, and reflect on their performance and how it could have been improved. Since they are competing against the other teams, the

dynamics of the competition are lively and enjoyable. As a result, they better understand how the Engineering Management curriculum, and the marketing class in particular, helps them become more effective engineers who can deal in the world of business.

The simulation allows the students to make the typical engineering errors in product development. They might base their decisions on their own opinions and values, and not on the perception and values of the customers. In the simulation, the teams can acquire market information, but they must pay for it. The simulation also prepares the class, so that subsequent class discussions about typical engineering behavior can be based not only on the information in the text and the comments from the lecturer, but also from their own experience in the simulation. As a result, much deeper learning, with longer lasting impact, is expected through this experience.

In January 2003, the students in EMgt-351, Industrial Marketing, participated in this simulation during the class period. A few weeks later they were asked to respond to a web-based survey very similar to the one described for the EMgt-475 class. Thirty four out of the 35 students enrolled answered the questionnaire. They were asked to determine and record their Myers-Briggs personality type, whether they were undergraduate or graduate students, their home department, work experience, current GPA and grade expectations. In addition they were asked to assess their opinion regarding the class and the Palmtop simulation. Some of the more useful questions were as follows:

1. I find the content of this course to be of interest.
2. I enjoy the discussion style of the course.
3. I find the instructor to be knowledgeable.
4. I find that having the lecture slides available on the web useful.
5. I find Blackboard to be easy and convenient to use.
6. I think the Palmtop simulation was a valuable learning opportunity.
7. The Palmtop simulation helped me understand the need for marketing.
8. The simulation helped me understand the need for marketing.
9. The Palmtop simulation was fun.
10. I experienced feelings about new product development such as joy and frustration.
11. I think this course will help me in my career after graduation.

In relation to each of these statements, the 34 students chose:

Choice	*Abbreviation*	*Value*
Strongly Agree	(SA)	2
Agree	A	1
Neutral	N	0
Disagree	D	-1
Strongly Disagree	SD	-2

The results of this survey are shown in Table 1.

TABLE 1: STUDENT OPINION SURVEY IN MARKTING CLASS

	Mean score	SA/A	N	D/SD
Interesting course	1.38	31	3	0
Enjoy discussions	1.06	27	6	1
Instructor knowledgeable	1.50	34	0	0
On-line slides useful	1.82	34	0	0
Blackboard easy to use	1.06	28	4	2
Palm experience valuable	1.09	27	5	2
Need for marketing	0.74	21	9	4
Meaning of marketing	0.68	20	10	4
Simulation was fun	1.18	28	4	2
Experienced feelings	0.85	28	6	0
Will help in career	1.32	31	3	0

All the responses were favorable with mean scores close to the value of "Agree" (1.0). The highest score was for having on-line access to the lecture slides, with a mean score of (1.82). Twenty-eight students strongly agreed that it is a great value, and the other six students agreed with the statement. There were also strong scores for the level of interest in the course, the expectation that it will help in their careers, and assessments of the instructor. Regarding the Palmtop simulation, the mean scores are positive and also close to the value of "Agree". The highest of the Palmtop scores was on fun (1.18). The students did enjoy it. They also saw it as a valuable exercise (1.09). The ability to help explain the need for marketing (0.74), the meaning of marketing (0.68) and to experience feelings of joy and frustration as part of new product innovation (0.85) was also evident, but not quite as strongly.

Five of the students are taking the class through a synchronous distance format. They were connected through a conference phone line for reliable voice transmission, and they saw streaming video on the web. However, they were frustrated and confused since the simulation creates an unstructured environment. They had considerable difficulties communicating with the other distance students to clarify the situation and create team consensus and decisions. It is challenging to have a synchronous distance activity in which simulations are used in unstructured collaborative team environments.

The student responses do vary depending on their personality types. The Myers-Briggs Personality Types are based on the four dimensions: Extroverted (E) vs. Introverted (I); Intuitive (N) vs. Sensing (S); Feeling (F) vs., Thinking (T); and Judging (J) vs. Perceiving (P). Since each student can be categorized as having a preference in each of the four dimensions, the student evaluations regarding the Palmtop simulation can be compared for each of these dimensions as can be seen in Table 2. The data that is presented is the difference between the mean score for the group of student with the specific personality type compared to the mean for all students for the statement that the Palmtop experience was valuable, and that it was fun. For example, extroverted students have a mean score for agreement with the value statement of 1.29, while the average for all students is 1.09. The table displays that these students had an average response 0.20 higher than the mean for all students.

TABLE 2: SIMULATION ASSESSMENTS BASED ON PERSONALITY TYPE.

Type	*Count*	*%*	*Value*	*Fun*
All students	34	100%		
Extroverted	21	62%	0.20	0.30
Introverted	13	38%	-0.32	-0.49
Intuitive	20	59%	-0.14	-0.08
Sensing	14	41%	0.14	0.05
Feeling	10	29%	0.31	0.52
Thinking	24	71%	-0.13	-0.22
Judging	28	82%	0.16	0.07
Perceiving	6	18%	-0.76	-0.35

This data shows that

- Engineering Management students have a wide range of personality types. Common types were Extroverted, Intuitive, Thinking and Judging, yet there were only six ENTJs in the class. As a matter of fact, out of the sixteen possible personality type combinations, this class represents 11 of them.
- The data also shows that the personality types that most appreciated the simulation exercise were: Extroverted, Sensing, Feeling and Judging. However, there is considerable spread of responses within all the groups. This means that there are certain types of students that are particularly motivated by a participatory, team-oriented simulation exercise. However, even those that did not have as high assessment of the simulation were still positive about the Palmtop simulation.

Summary

Simulations and other modes of class presentations can enhance the learning environment in Engineering Management courses. There is a wide range of ways in which these enhancements can be implemented that provides a numerous ways that the challenges of students with diverse backgrounds can be addressed. The examples in the quality and the marketing courses provide alternative ways that the key learnings can be presented to the students. Simulations allow for quality and marketing concepts to be personally experienced enhancing the theoretical concepts that are introduced in the classes.

The asynchronous simulations enable the student to perform them at their convenience and at their own pace. Even though the synchronous simulations lack the convenience and flexibility found in the prior simulations, they do allow for interaction among students. In the case of the marketing simulation, the interaction is critical and the synchronous simulation makes it more interesting and realistic, however, it did not work well for this group of distance students.

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